CoastSnapWA: Final Report

Prepared for the Peron Naturaliste Partnership

December 2020

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Document History:

REVISION	DATE	NOTES	AUTHOR	REVIEWED
A	9/12/2020	Draft sent to PNP for initial review	MVWC	JEH
B	17/12/2020	Draft send to PNP and DoT for review	MVWC	JEH
0	29/12/2020	Final report	MVWC	JEH

Contents

1. Executive Summary

Coastal monitoring data is critical for effective coastal management and long-term coastal planning. However, it is often difficult to capture relevant coastal data (e.g. shoreline position, beach width) with adequate temporal resolution to measure coastal processes across a range a timescales. Furthermore, data collection is often expensive and requires specialised equipment and expertise thereby limiting any engagement with local citizens and dissemination of results to the public. CoastSnap is a coastal monitoring technique that relies on community-sourced smartphone imagery to measure key coastal parameters (beach width, shoreline position) and understand coastal processes (e.g. erosion and accretion). CoastSnap differs from other photo monitoring techniques in that it fixes the camera position through the use of a camera cradle. By fixing the camera position, features in the field of view can be surveyed and used to rectify the imagery to real-world coordinates, allowing the photos to be used to accurately record shoreline position. CoastSnap imagery is collected directly by community members and then uploaded via social media or QR code to be processed. The system is a powerful tool that engages the community in coastal management and planning, initially through the collection of coastal monitoring data (imagery) and then again on social media where the community can see all the collected imagery and corresponding analysis.

This report summarises the establishment of the first 9 CoastSnap sites in Western Australia (CoastSnapWA) through a collaboration between the Peron Naturaliste Partnership (PNP) and the University of Western Australia. The CoastSnapWA sites were spread throughout the PNP member local governments, with one site per local government from Rockingham to Busselton. Each site, with the exception of Herron Point (Shire of Murray) included a camera cradle and CoastSnapWA signage, and all were in place by July 2020 (later than expected due to COVID-19). The Shire of Murray already had existing infrastructure and signage for a similar, photo-based flood monitoring program, thus one of these sites was included as a CoatsSnapWA site. From July 2020 to December 2020, CoastSnapWA received over 400 images. The images were used to generate timelapse imagery to investigate changes in beach state and were also quantitatively analysed to determine shoreline position and beach width. As the CoastSnapWA data collection has only covered approximately 6 months to date, historical shoreline positions were also mapped using publicly available satellite imagery from 1986 to 2019 (using the 'CoastSat' tool). This data provides key long-term context for the CoastSnapWA sites as well as

insight into the alongshore variability in shoreline dynamics in the PNP region. Importantly, both CoastSnapWA and CoastSat can provide coastal observations at relatively high temporal resolution (order weekly) that can complement existing long-term monitoring datasets that have been collected at lower temporal resolution (monthly, seasonally, annually).

2. Introduction

The coastal zone is a focal point for human development, economic and recreational activity, and environmental and ecosystem services. This is particularly the case in Australia with ~80% of the population living within 50 km of the coastline. The coastline however is not a static feature and thus coastal management and planning must be informed by an understanding of the coastal dynamics. Of the range of coastal landforms, beaches in particular are highly dynamic across a range of timescales. For example, extreme storms can cause shoreline retreat on the order of 50 m (Hansen & Barnard, 2010), whereas seasonal to interannual changes can be in the order 100 m (Harley et al., 2011), and decadal erosion or accretion trends can be in excess of several meters /year (Luijendijk et al., 2018; Vos, Harley, et al., 2019). Coastal monitoring data underpins effective coastal management and planning. However, collection of relevant coastal monitoring data (e.g. shoreline position, beach profiles) is often time and labour intensive and has not always been viewed as priority data; thus, observational datasets are often limited and comprised of sporadic data collected using different techniques.

The temporal resolution of observational datasets directly dictate the coastal processes that can be measured (Splinter et al., 2013). One of the most extensive datasets available is the historical coastal movements dataset organised by the Western Australia Department of Transport (DoT). This dataset consists of shorelines mapped from historical aerial imagery and covers the time period from 1943 to 2016, with additional imagery collected approximately every 5 years over much of the coastline (Stead, 2018). Outside of this dataset, coastal monitoring data is generally collected by local governments using a variety of techniques (e.g. to support specific coastal development/infrastructure or as part of on-going coastal monitoring). Due to the targeted nature of this data collection, coastal monitoring efforts are often limited spatially (focused on one or a few sites) and temporally (only collected for short period). These limitations translate to uncertainty in coastal management and planning strategies as there is not often sufficient data to resolve coastal changes across the full spectrum of timescales (from storm event to decadal trends) or spatial scales (from tertiary to secondary sediment cell) of interest. However, using conventional coastal monitoring techniques to achieve the frequency and long-term data required to resolve seasonal to inter-decadal shoreline variability at individual beaches to regional scales is often cost-prohibitive.

Remote sensing techniques (fixed cameras, satellites) can provide the frequency of measurements, however, require costly infrastructure, expertise, and upkeep. With the proliferation of high quality cameras on smartphones, publicly collected imagery can now be used for coastal monitoring. This has led to development of ‘CoastSnap’ a global coastal monitoring effort that relies on community-sourced smartphone imagery (Harley et al., 2019). CoastSnap was started in southeastern Australia, but now exists globally (https://www.coastsnap.com/map). The basic premise behind CoastSnap is that a fixed photo monitoring location is established that local beach users can ‘snap’ photos from. By accurately measuring the fixed photo position and features within the field of view, community-sourced imagery can be rectified and used to map shoreline position with a horizontal positional accuracy of 5 m (or better) (Harley et al., 2019). A well-positioned CoastSnap site may be visited by community members daily, thus providing high temporal resolution coastal observations. Furthermore, CoastSnap has the added benefit of directly engaging local community members in coastal monitoring, thus raising awareness of coastal hazards (e.g. coastal erosion) and general coastal processes (e.g. seasonal variability).

The Peron Naturaliste Partnership (PNP) is a coalition of 9 local governments (LGs) in southwest Western Australia. These governments occupy ~250 km of coastal and estuarine habitat and have recognised that climate change-induced variability in coastal processes (e.g. sea level rise, increased storm intensity, etc.) poses a significant threat to the entire region’s natural and built coastal assets and values. The PNP is currently collecting coastal monitoring data using low-cost techniques such as beach width measurement and photo monitoring as part of a 10-year regional coastal monitoring program (RCMP) (Damara Pty Ltd, 2015; UWA, 2018). As part of the implementation of the first year of the RCMP, it was suggested that CoastSnap could be incorporated as a coastal monitoring technique (UWA, 2018).

This project established the first 9 CoastSnap sites in Western Australia (CoastSnapWA). To provide historical context for the CoastSnapWA shoreline changes, we also have conducted a historical reconstruction of shoreline positions from publicly available satellite images. Below we provide the details of the CoastSnap methodology and workflows, the analysis of the CoastSnapWA imagery received to date and provide the methods and results for the satellite shoreline extraction. Finally, we summarize the benefits of CoastSnap as a coastal monitoring tool and discuss ways forward for the CoastSnapWA project.

3. Methodology

3.1. Community-sourced smartphone imagery

CoastSnap relies on smartphone imagery captured and uploaded by community members. As such, site selection is a balance between community engagement (i.e. choosing a site that is regularly visited by community members) and data quality (i.e. choosing a site than enables good imagery of the coast). For the PNP, CoastSnapWA sites were also required to be in the vicinity of on-going monthly coastal monitoring locations that are part of the PNP's 10-year regional coastal monitoring program (RCMP). After consultation with the local governments, 9 CoastSnapWA sites were selected throughout the PNP region (Figure 1). These were located at the Mersey Point Jetty (Shoalwater Bay, City of Rockingham), Henson Street Park (Silver Sands, City of Mandurah), Preston Beach (Preston Beach, Shire of Waroona), Binningup beach playground (Binningup, Shire of Harvey), Dolphin Discovery Centre (Koombana Bay, City of Bunbury), Eaton foreshore (Eaton, Shire of Dardanup), Dalyellup south staircase (Dalyellup, Shire of Capel), Busselton Jetty (City of Busselton) (Figure 1). The Shire of Murray already has a similar photographic monitoring project for monitoring water levels in the estuary, therefore, their Herron Point site was adopted as a CoastSnapWA site.

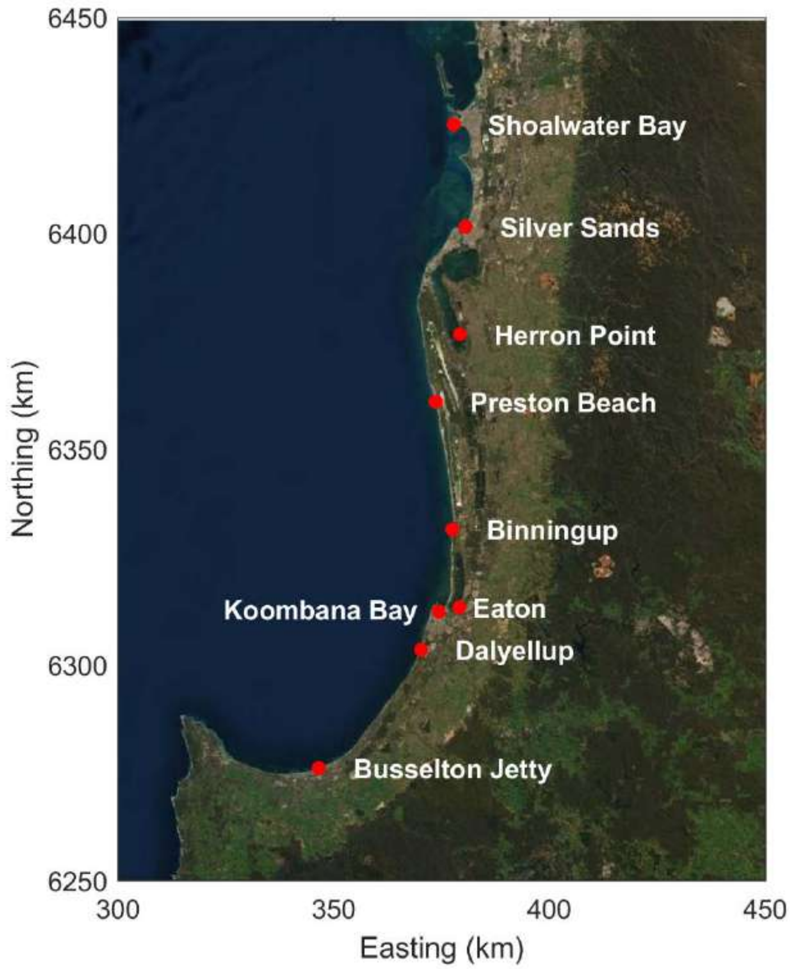


Figure 1. Overview of CoastSnapWA sites within the PNP region.

Following site selection, each site was visited by UWA and PNP team members to design CoastSnapWA smartphone brackets for each site (Figure 2). The brackets and mounts were then fabricated in stainless steel and delivered to the local governments for installation. Additionally, custom CoastSnapWA signs were designed in consultation with PNP local governments and were specific to each site (Figure 2). The signage includes simple instructions for how to participate and contribute to CoastSnapWA as well as site specific hashtags (#CoastSnapShoalwaterBay, #CoastSnapSilverSands, #CoastSnapPrestonBeach, #CoastSnapBinningup, #CoastSnapKoombanaBay, #CoastSnapEaton, #CoastSnapDalyellup, #CoastSnapBusseltonJetty) and QR codes that were used for uploading imagery to a database. Note, to avoid duplicating the Shire of Murray photo monitoring program, no official

CoastSnapWA signage was installed for Herron Point; therefore, there is no CoastSnapWA hashtag for this site. Finally, a general CoastSnap email address was established and included on the signage – coastsnapwa@gmail.com – for community members who wanted to contribute photos via email. User-contributed photos were archived locally on UWA servers as well as on an Amazon Web Services (AWS) S3 ‘bucket’.

Figure 2. CoastSnapWA bracket and signage at our Silver Sands site (Mandurah).

A CoastSnapWA Facebook page was also established (www.facebook.com/coastsnapwa) (Figure 3) to facilitate photo upload (i.e. directly to Facebook page) but, more importantly, distribution of CoastSnapWA imagery and analysis to community members. After the CoastSnapWA brackets and signage were installed by each local government, UWA conducted differential GNSS surveys of each site to collect ground control points (GCPs). This involved surveying fixed objects within the camera field of view (FOV) as well as conducting ‘roving’ surveys that covered larger portions of the FOV. The GCPs enable CoastSnapWA imagery to be rectified to real-world coordinates and facilitate quantitative measurements of beach width and shoreline position (Harley et al., 2011, 2019; Holman & Stanley, 2007). GCPs were also used to establish a 'control' photo for each site which was used to co-register all CoastSnapWA imagery prior to analysis (see below).

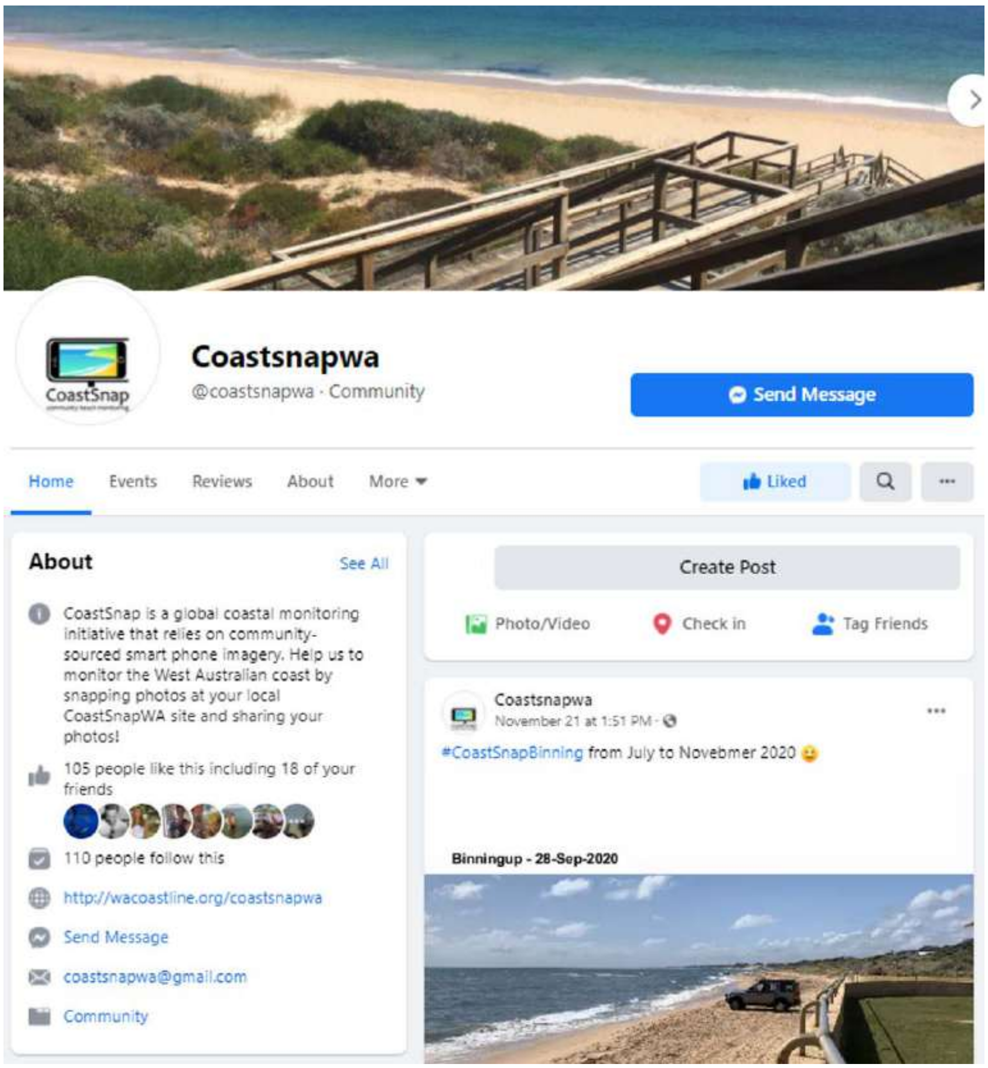


Figure 3. Homepage for the CoastSnapWA Facebook page

Community-sourced imagery was retrieved from the various platforms (Facebook, AWS database) for analysis. The processing workflow consists of several steps, including: (1) image download and database entry; (2) file renaming and archiving; (3) image registration and rectification; and (4) shoreline mapping (Figure 4). Image download from both Facebook and

AWS was conducted weekly by UWA. Image metadata was then entered into the CoastSnapWA database, which contains information on site, image capture time, and CoastSnapWA user name (if supplied). The remaining workflow is then conducted using the CoastSnap-Toolbox, which is a publicly available Matlab package developed by researchers at the University of New South Wales (UNSW, https://github.com/Coastal-Imaging-Research-Network/CoastSnap-Toolbox).

Figure 4. Example CoastSnapWA workflow using the Graphical User Interface (GUI). Example is from Koombana Bay from 20 November 2020. User image is displayed on the left, rectified image on the right and mapped shoreline displayed in yellow on both images.

Downloaded images are first renamed to a coherent and consistent structure that corresponds to the naming convention used by the wider coastal processes community (e.g., ARGUS) (Holman & Stanley, 2007); renamed files are then archived by site and then by year. These processed images can then be rectified (mapped to real-world coordinates) via two methods: (1) images can be individually rectified using the measured GCPs; or, (2) images can be co-registered to the control image whose rectification parameters are already known. Both methods have been shown to yield comparable accuracy for further quantitative analysis (Harley et al., 2019). Therefore, for each site, the control image was rectified using the measured GCPs and all other community-sourced imagery was co-registered to this image prior to further analysis. Image registration was completed using the 'align-photos' tool within Adobe Photoshop (Harley et al., 2019). After registration, the CoastSnap-Toolbox Graphical User Interface (GUI) was used to rectify each image and map the shoreline (Figure 4). Shoreline mapping is achieved by mapping the interface between 'wet' and 'dry' pixels. The shoreline calculated based on the colour divergence method using the red and blue colour channels of each image (Harley et al., 2011, 2019). First the 'Red minus Blue' (RmB) colour space is calculated for each image which optimizes the difference in intensities between 'wet' and 'dry' pixels; then a locally-adaptive thresholding algorithm is used to identify the shoreline. The thresholding algorithm utilises shore-normal transects to sample pixel intensities from the RmB image; this provides a bimodal distribution at each transect with clear peaks that correspond to 'wet' (water) pixels and 'dry' (sand) pixels. The optimum threshold between the two peaks is then calculated as:

$$RmB_{OPT} = 0.33(RmB_{WET}) + 0.67(RmB_{DRY}) \quad (1)$$

where RmB_{WET} and RmB_{DRY} are the RmB values of the wet and dry pixel peaks in the bimodal distribution, respectively. The shoreline (SL) is then extracted from the rectified image by contouring the RmB space along the optimum threshold value using the marching squares algorithm (Cipolletti et al., 2012). Shorelines using this method have been shown to correspond to the horizontal position of the upper swash zone (Harley et al., 2011, 2019).

The GUI also contains tools for calculating the shoreline change trend over some given period of time (e.g. preceding 60 days). To do this, estimates of the beach slope and tidal elevation at time of image capture are needed. Beach slopes for each site were calculated between -1.5 m and +1.5m AHD using the 2009 LiDAR available from the WA Department of Transport. Tidal elevations were derived from the FES2014 global tide model (Carrere et al., 2016), which ranks amongst the best barotropic ocean tide models for coastal regions (Stammer et al., 2014). Shoreline change trends calculated by the GUI only consider shorelines that were observed at similar stages of the tide (e.g. within ±0.05 m). However, it is also possible to apply a tidal correction (ΔSL) to every observed shoreline such that the shoreline position is corrected to some height datum (e.g. 0 m AHD). This is calculated as:

$$\Delta SL = \frac{z_{tide} - z_{datum}}{\beta} \quad (2)$$

where z_{tide} is the measured or modelled tidal elevation at the time of image capture, z_{datum} is the reference elevation shorelines will be corrected to (e.g., mean sea level, mean high water, etc.), and β is characteristic beach slope. The final, tide-corrected shoreline position is then calculated as:

$$SL_{corr} = SL - \Delta SL \quad (3)$$

Equations 2 and 3 were used to calculate a tide correction to 0 m AHD for each CoastSnapWA shoreline.

3.2. Satellite-derived shorelines

We used CoastSat, a publicly available Python toolkit (https://github.com/kvos/CoastSat), to extract shoreline positions from publicly available satellite imagery (Vos, Harley, et al., 2019; Vos, Splinter, et al., 2019). Complete details and validation of CoastSat can be found in Vos et al. (2019a, 2019b), so only a summary of the key methods are provided here.

CoastSat utilises GoogleEarthEngine (Gorelick et al., 2017) to access the public archives of Landsat-5, Landsat-7, Landsat-8, and Sentinel-2 imagery. The algorithm retrieves Tier 1 Top of Atmosphere Landsat imagery (30 m resolution available from 1985 to present) and Level-1C Sentinel-2 imagery (10 m resolution available from 2015 to present) for a defined region of interest and time period. The imagery is then pre-processed to enhance the spatial resolution of relevant bands for shoreline mapping. For the shoreline detection algorithm, the relevant spectral bands include the visible bands (red, green, blue), the near-infrared band and the short-wave infrared band. Landsat-7 and 8 also include a panchromatic band, which was used to increase the spatial resolution from 30 m to 15 m for the visible bands (Landsat-7 and 8) and the near infrared bands (Landsat-7). Landsat-5 imagery as well as Landsay-7 and 8 bands that could not be pansharpened were down-sampled to 15 m resolution using bilinear interpolation (Vos, Harley, et al., 2019). Sentinel-2 spectral bands are higher resolution than Landsat-7 and 8 (visible bands and near infrared = 10 m, short-wave infrared = 20 m) and to maintain the same resolution across all bands, bilinear interpolation was used to down-sample the short wave infrared band to 10 m. The shoreline detection analysis combines a sub-pixel resolution border segmentation method with an automated image classification (two layer Neural Network) to estimate the instantaneous sand/water interface (shoreline). First the modified normalized difference water index (MNDWI) is calculated to isolate 'land' from 'water'. Next, the optimum threshold separating 'sand' and 'water' is calculated from the distribution of MNDWI values for 'water' and 'sand' classes (as identified by the classification scheme). Finally, this threshold MNDWI value is contoured using the marching squares approach (Cipolletti et al., 2012; Vos, Harley, et al., 2019).

Here, we used CoastSat to analyse imagery at each CoastSnap site from August 1986 to December 2019 (~33 years). Murray and Dardanup, being estuarine and lacking sufficient beach area for satellite-derived shoreline detection, were not included in this analysis. Regions of interest for image download and analysis extended ±3 km alongshore from each CoastSnap site (except for Koombana Bay, which focused only on the beach at Dolphin Discovery Centre). Prior to analysis, the underlying image classification scheme was re-trained using imagery specific to the PNP coast; thus, the Neural Network was optimized for shoreline detection along the southwest WA coastline. During analysis, images that had poor rectification (rectification accuracy greater than 10 m for Landsat, or a -1 flag for Sentinel-2) were removed. Shorelines were tidally-corrected to mean sea level (0 m Australian height datum; AHD) using Equations 2 and 3, tidal elevations (in AHD) measured at Department of Transport tide gauges (Fremantle and Bunbury) and beach slope derived from DoT 2009 LiDAR dataset. Fremantle tides were used for Shoalwater Bay, Silver Sands, and Preston Beach; Bunbury tides were used for Binningup, Koombana Bay, Dalyellup, and Busselton Jetty. Tidal correction and shoreline change analysis was conducted using 50 m alongshore-spaced, shore normal transects.

The satellite shorelines were intended to provide long-term context for the shoreline dynamics at the CoastSnapWA sites as well as to provide preliminary assessment of the applicability of this technique within the PNP region. DoT maintains the coastal movements dataset along much of the WA coastline. This dataset includes historical positions of vegetation lines as well as the horizontal position of 0 m AHD contour. To provide a qualitative comparison of the satellite-derived shorelines and the DoT coastal movements dataset, the same shore normal transects were intersected with the vegetation line contours available from the DoT dataset. Shoreline change analysis below is presented relative to the median shoreline position measured at each transect for each dataset.

3.3. Metocean data

Quantifying the drivers of coastal change observed in both the CoastSnapWA and CoastSat analysis was beyond the scope of the project. However, to demonstrate the applicability of these techniques for generating useful coastal monitoring data we analysed available wave and water level data from DoT wave buoys and tide gauges located along the PNP region. Specifically, we utilised the wave buoy data from Cape Naturaliste, Mandurah, and Rottnest Island (retrieved from the Australian Ocean Data Network, AODN), and the water level data from the Port Geographe and Fremantle Fishing Boat Harbour tide gauges (retrieved directly from DoT).

4. Results

4.1. CoastSnap – user engagement

Although the project commenced in May 2019 and site installations were planned for December 2019, there were several unanticipated delays due to coordinating across all of the PNP governments and site selection. Issues around site selection were related to finding sites that had suitable coastal aspects and elevation for imagery, infrastructure for stand installation and ground control points, and were subject to some coastal movement. All signage and infrastructure was installed by each local government by March 2020, which, unfortunately coincided with the spread of COVID-19 and corresponding movement restirctions. As such, the CoastSnapWA project did not officially launch until July 2020. Therefore, the analysis in this report covers 01 July 2020 (the official 'launch' date of CoastSnapWA) to 27 December 2020. However, all images and mapped shorelines will be delivered to PNP through to 31 December 2020.

Once COVID-19 restrictions were eased and CoastSnapWA was officially launched, each site began to receive community-sourced images from all three upload options (Facebook, QR code, Email). To date, CoastSnapWA has received over 413 images (~82 images per month) across all sites (Figure 5). The vast majority of imagery was uploaded via the QR code that is displayed on the CoastSnapWA signage (Figure 5); whereas e-mail and Facebook were used approximately equally. The widespread use of the QR code meant that data seamlessly streamed to the CoastSnapWA image database, with all image metadata preserved (e.g., upload timestamp); thus enabling subsequent quantitative analysis of the imagery. This is a key advantage of using the QR code for upload (instead of just relying on social media), as these critical metadata are often removed from social media images but are needed for accurate quantitative analysis (e.g. to determine the tidal stage when the photo was taken).

There was variability amongst the sites in regards to total number of uploads, unique users (unique individual 'CoastSnappers'), as well as upload type (Figure 5 and 6). The most uploads occurred at Shoalwater Bay, Busselton Jetty, and Koombana Bay, respectively. These sites all experience high visitor rates due to the tourist attractions at each site (e.g. Penguin Island, Busselton Jetty, Dolphin Discovery Centre). Similarly, staff and volunteers at these sites were engaged to take photos during their shifts.

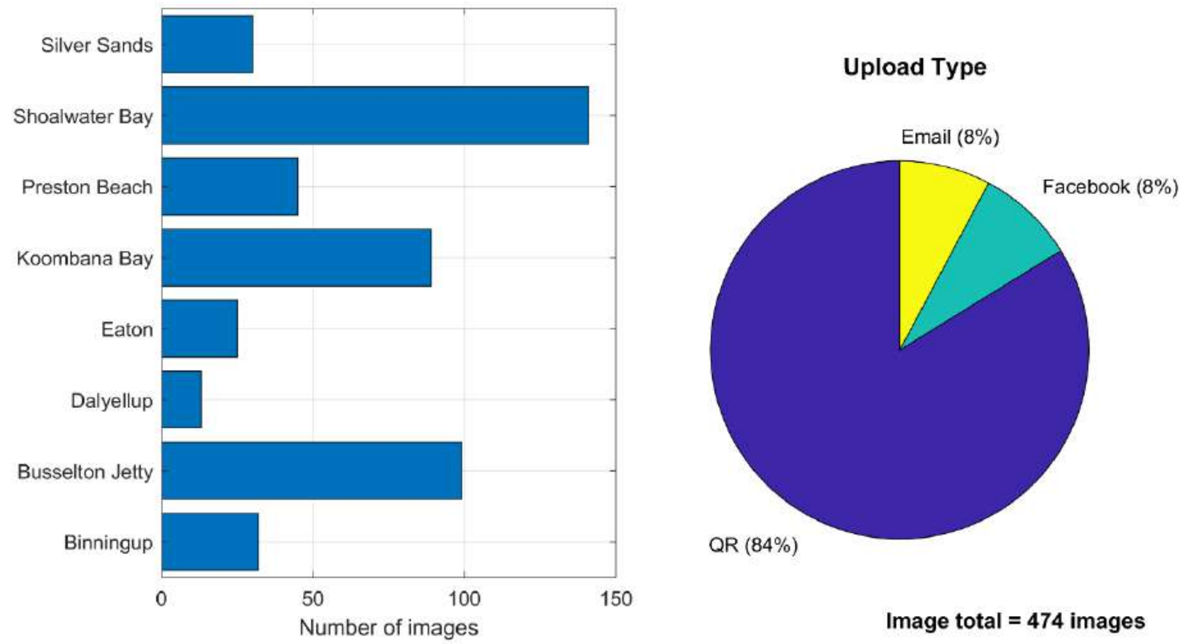


Figure 5. Breakdown of total number of images by site (a), and by upload type (b). Note, metrics are valid up to 27 December 2020.

Most sites experienced a rapid upload rate after initial launch (e.g. between July and August 2020; Figure 6). Although this high upload rate generally levelled off from September onwards, some sites (Shoalwater Bay, Koombana Bay, Busselton Jetty) maintained high upload rates across time (Figure 6). This is likely related to visitation rates and engagement with staff at these locations.

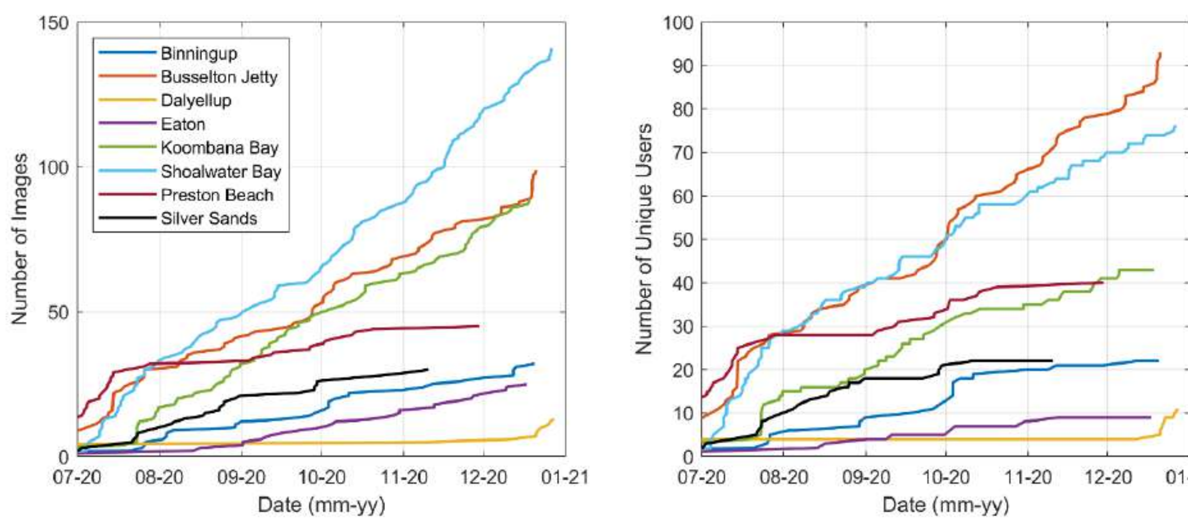


Figure 6. Cumulative number of images and unique CoastSnapWA users at each site.

Similarly, most sites experienced comparable total numbers of images as number of unique users (Figure 6). This suggests that each new image was uploaded by a new CoastSnapWA user (or by one who elected to not be named). Notable exceptions to this pattern are Koombana Bay (80 images by 40 users) and Shoalwater Bay (140 images by 75 users), suggesting that these sites have 'local champions' who are consistently contributing CoastSnapWA photos for their local site.

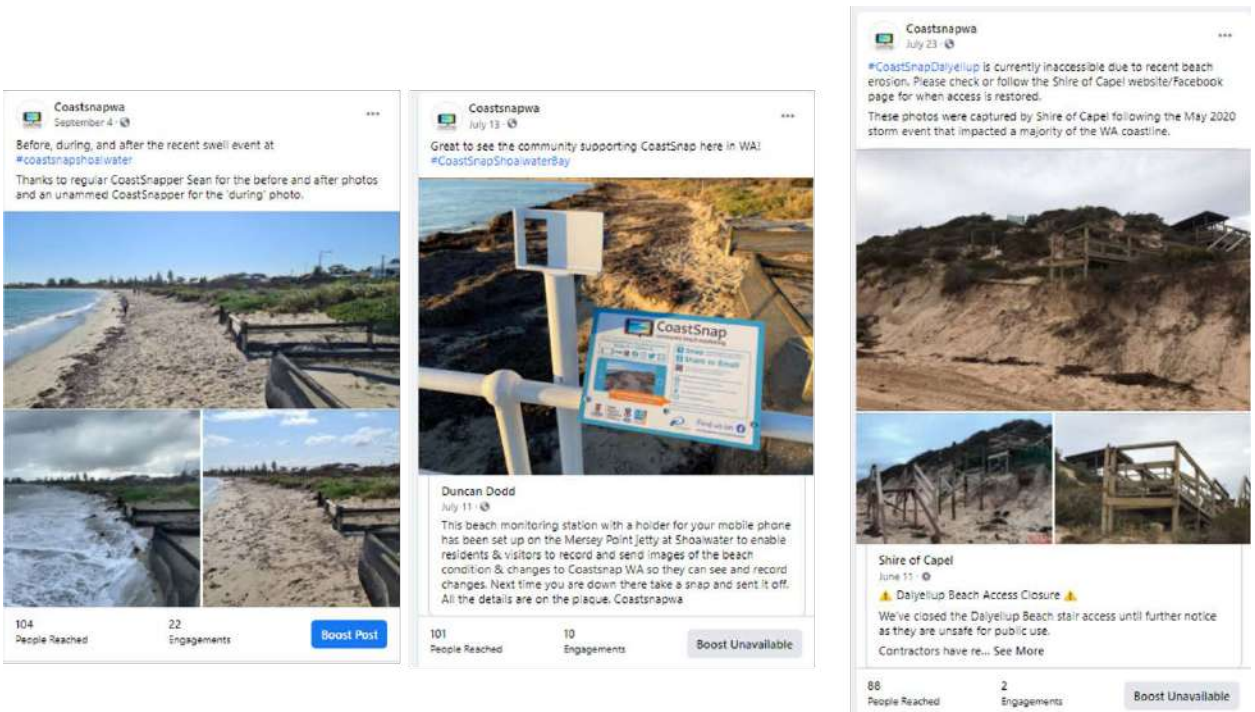


Figure 7. Example posts from the CoastSnapWA Facebook page.

The CoastSnapWA Facebook page was the main venue for displaying CoastSnapWA imagery and results. We received several photos from users via direct upload to the Facebook page or through Facebook messages. The page has over 100 likes/followers, averages ~4 engagements per day (any click or other social media engagement on post), and 'reaches' ~30 people per day ('reach' includes any CoastSnapWA content reaching a user's screen), with a maximum of 721 people reached for a single post. The Facebook page also allowed us to notify users of beach closures at CoastSnapWA sites (e.g. Dalyellup) and share pre- and post-storm photos supplied by users (e.g. Shoalwater Bay; Figure 7).

4.2. CoastSnap – quantitative analysis

Quantitative analysis from CoastSnapWA imagery involves image registration to a 'control' image, rectification using the known geometry of control image, and finally, shoreline mapping (e.g. Figure 8). All images that were contributed by users were archived within the CoastSnapWA image database (total = 474 images). Dalyellup received only 9 images during the analysis period (July – December 2020) due to beach access being closed following beach erosion in May 2020. However, Dalyellup beach access has recently been restored (late November 2020) and the CoastSnapWA signage has also been re-installed; thus, we expect to see a continued increase in Dalyellup imagery in the near future. Despite receiving limited imagery thus far, all of the additional work to establish CoastSnapWA-Dalyellup is complete (e.g. site survey, control image). Therefore, once imagery becomes available, the full CoastSnapWA workflow can be applied to determine shoreline change the community-sourced imagery (see Appendix 1 for example shoreline detection at Dalyellup).

Table 1. Breakdown of CoastSnapWA image processing, including total number of available images, number of rectified images, and number of shorelines mapped. Note, data is current to 27 December 2020.

Site	Number of images	Number of rectified images	Number of shorelines mapped
Binningup	31	28	22
Busselton Jetty	93	85	68
Dalyellup	9	7	5
Eaton	25	23	20
Koombana Bay	86	80	63
Preston Beach	41	0	0
Shoalwater Bay	141	135	106
Silver Sands	29	22	16

Despite receiving a relatively large number of images, not all of these images were suitable for quantitative analysis (Table 1). For example, some uploaded images were not taken from the CoastSnapWA bracket and thus did not include the correct field of view to enable image rectification. Similarly, some images that were able to be rectified were not able to be used for shoreline detection. This was general due to the lighting conditions within the imagery or other factors that prevented the shoreline edge detection algorithm from working accurately.

Figure 8. Example shoreline detection at Binningup. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Similar examples for each CoastSnapWA site can be found in Appendix 1.

Preston Beach was the only site that was unable to be used for quantitative analysis. Preston Beach is unique amongst the CoastSnapWA sites in that it is devoid of any coastal infrastructure. Thus, there are limited to no options for fixed ground control points that can be used for image rectification. In collaboration with Shire of Waroona, we installed star pickets in the dunes to try to enable image rectification, but this did not improve the rectification solution. To achieve a high quality (and accurate solution), significantly more pickets would be required. This was considered to be unfeasible considering that pickets are likely to be undermined by natural coastal processes and/or human intervention. We were able to establish a control image for Preston Beach, however, as the field of view only contains limited distinguishable features (e.g. fixed infrastructure) we were unable to co-register the images. Thus, CoastSnapWA imagery from Preston Beach can only be used for qualitative photo monitoring at this time.

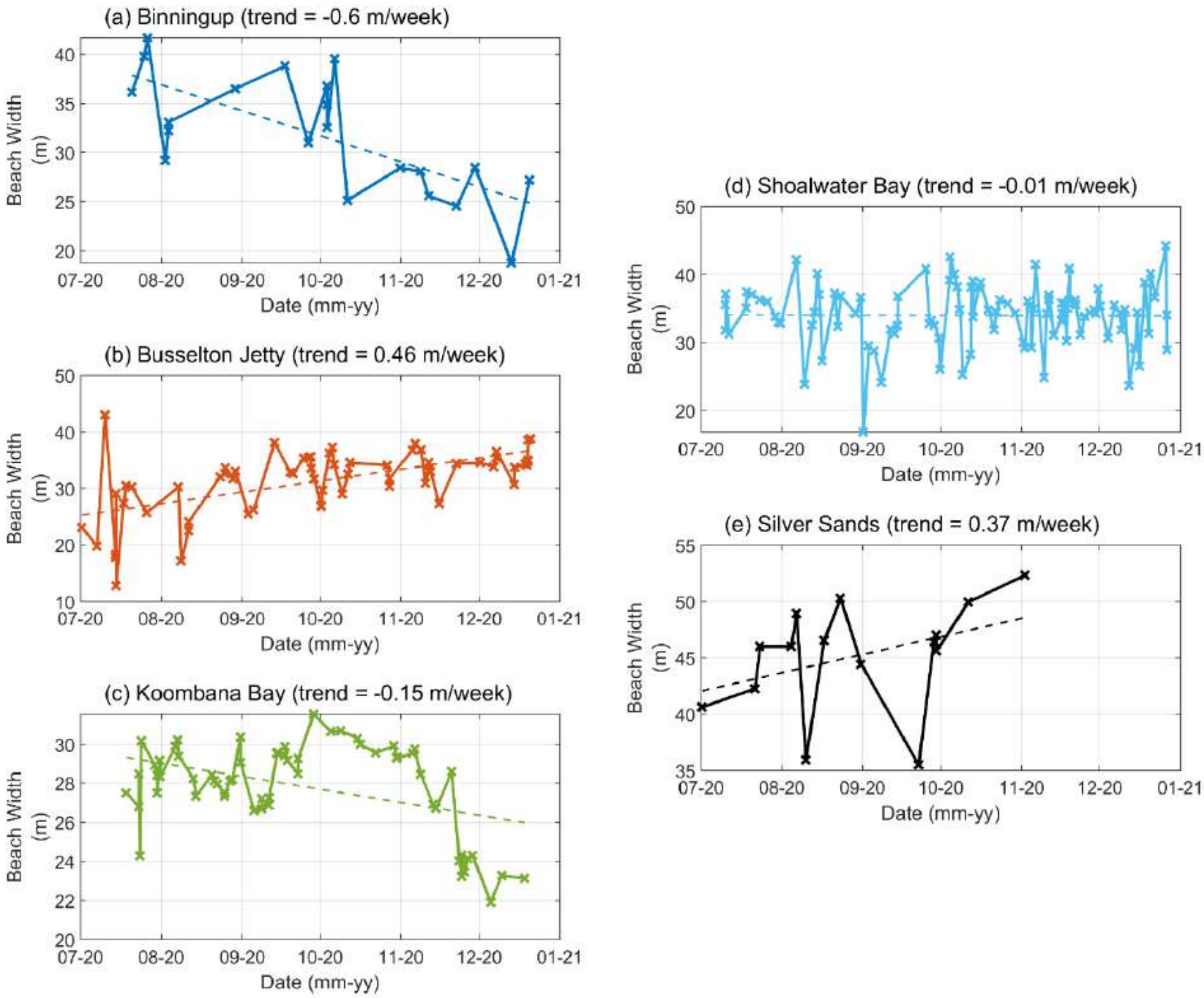


Figure 9. Shoreline change from community-sourced imagery at the CoastSnapWA sites.

Quantitative analysis of CoastSnapWA imagery yielded at least monthly observations of shoreline position and beach width at all sites (Figure 9). However, at the more frequented sites, we received daily to weekly imagery (e.g. Shoalwater Bay and Koombana Bay). Using the tide-corrected shoreline positions, an erosive trend was observed at Binningup (~-0.6 meters/week) and Koombana Bay (-0.15 meters/week), while a positive trend was observed at Busselton Jetty (0.46 meters/week) and Silver Sands (0.37 meters/week) (calculated from 1 July 2020 to 27 December 2020). Shoalwater Bay showed no trend in beach width (Figure 9). As the PNP has been collecting monthly beach widths in the vicinity of the CoastSnap locations since 2017 (UWA, 2018), we endeavoured to compare the measurements from both methods (Figure 10). However, we note that these methods are not necessarily directly comparable as the PNP beach widths have not been tide-corrected and we are unaware of the exact date and time of beach width measurement, which would be required to tide-correct the measurements, so these data are presented as representative of the entire month. Furthermore, despite efforts to select CoastSnapWA locations that were co-located with PNP beach width monitoring (e.g. Figure 10g), this was not possible for many locations (e.g. Figure 10f). Thus, the CoastSnapWA site may be separated from the closest beach width point by several hundred meters, and have a field of view oriented in the opposite direction (Figure 10). Despite the limited data available for comparison, the results between the CoastSnapWA data and the in situ PNP beach widths are generally promising for some sites. For example, both datasets capture the beach erosion at Silver Sands in August 2020. Importantly, this comparison highlights the increased temporal resolution provided by the CoastSnapWA imagery. More representative comparisons can be made as the CoastSnapWA dataset increases in length and by tide-correcting the PNP beach widths.

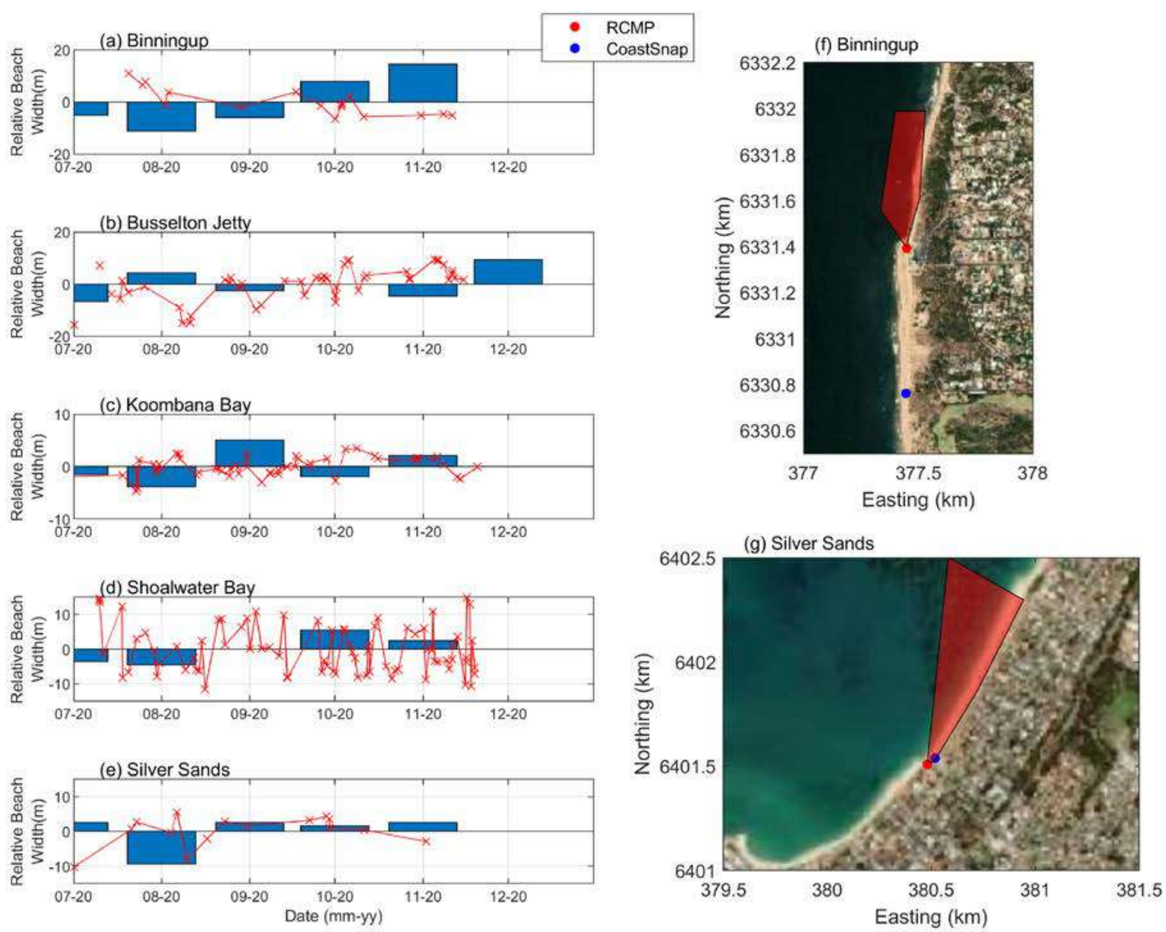


Figure 10. Comparison of PNP monthly beach widths (blue) and CoastSnapWA (red) from July 2020 to November 2020. Example CoastSnapWA site locations (and field of view, red polygons) compared to PNP

monthly beach width location are provided for Binningup (f), and Silver Sands (g). Median shoreline position for both datasets are calculated over the CoastSnapWA time period (July 2020 to December 2020).

The quantitative approach and relatively high temporal resolution of observations of CoastSnapWA enables analysis of the drivers (waves, water levels) of the observed shoreline change (Figure 11). Interestingly, several events stand out during the July 2020 – December 2020 study period. For example, there is some beach erosion at Busselton Jetty and Shoalwater Bay between August and September, likely related to corresponding elevated water levels. Another erosion event occurred in early September, but this time was associated with a large wave event. Finally, there is a clear beach accretion spike in October that is associated with the lowest observed water levels.

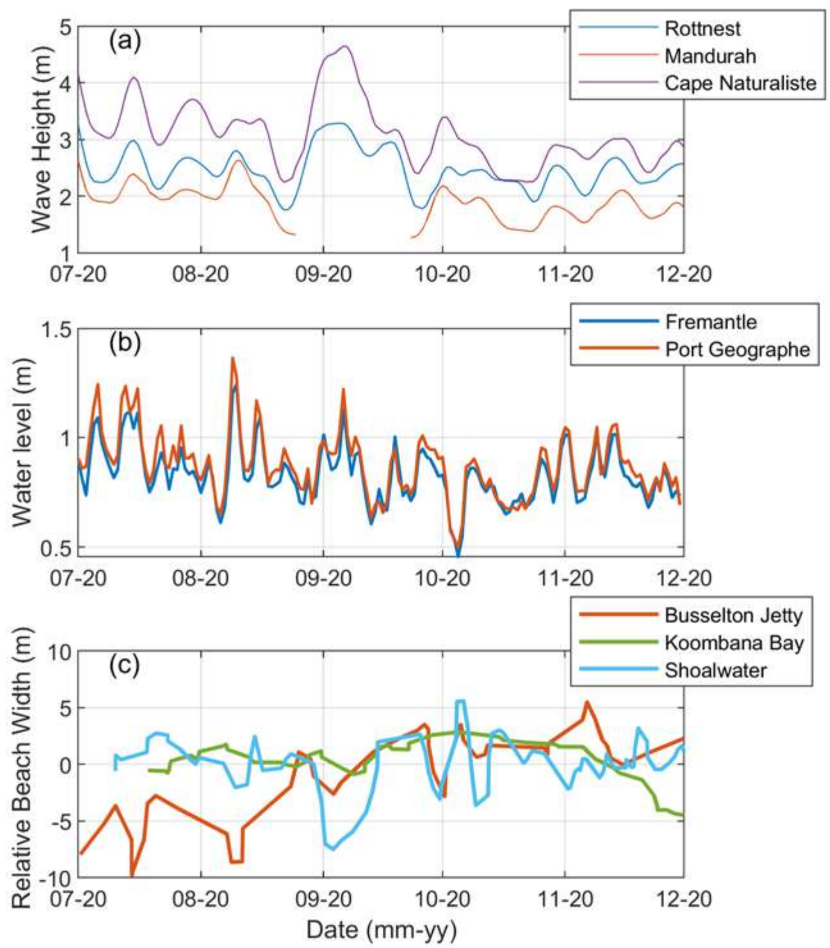


Figure 11. Comparison of morphodynamic drivers (waves and water levels) to observed CoastSnap beach width changes. Significant wave height (a) was retrieved from the Australian Ocean Data Network (AODN). Water level data (b) was retrieved from DoT; note, Fremantle datum is the Fremantle low water mark (LWM) and the Port Geographe datum is chart datum.

4.3. Satellite derived shorelines

The use of satellite-derived shorelines provided larger spatial scale and longer temporal scale observations for each CoastSnapWA site (Figures 12-15). Most of the beaches within the CoastSnapWA sites' field of view showed long-term accretionary trends from August 1986 to December 2019. However, there was clear alongshore variability (erosion and accretion) in beach response. For example, there were significant areas of erosion within Shoalwater Bay, Silver Sands, and Binningup adjacent to areas of long-term accretion (Figure 12-13). Below we focus on the historical time-series for a representative transect within the field of view of each CoastSnapWA site.

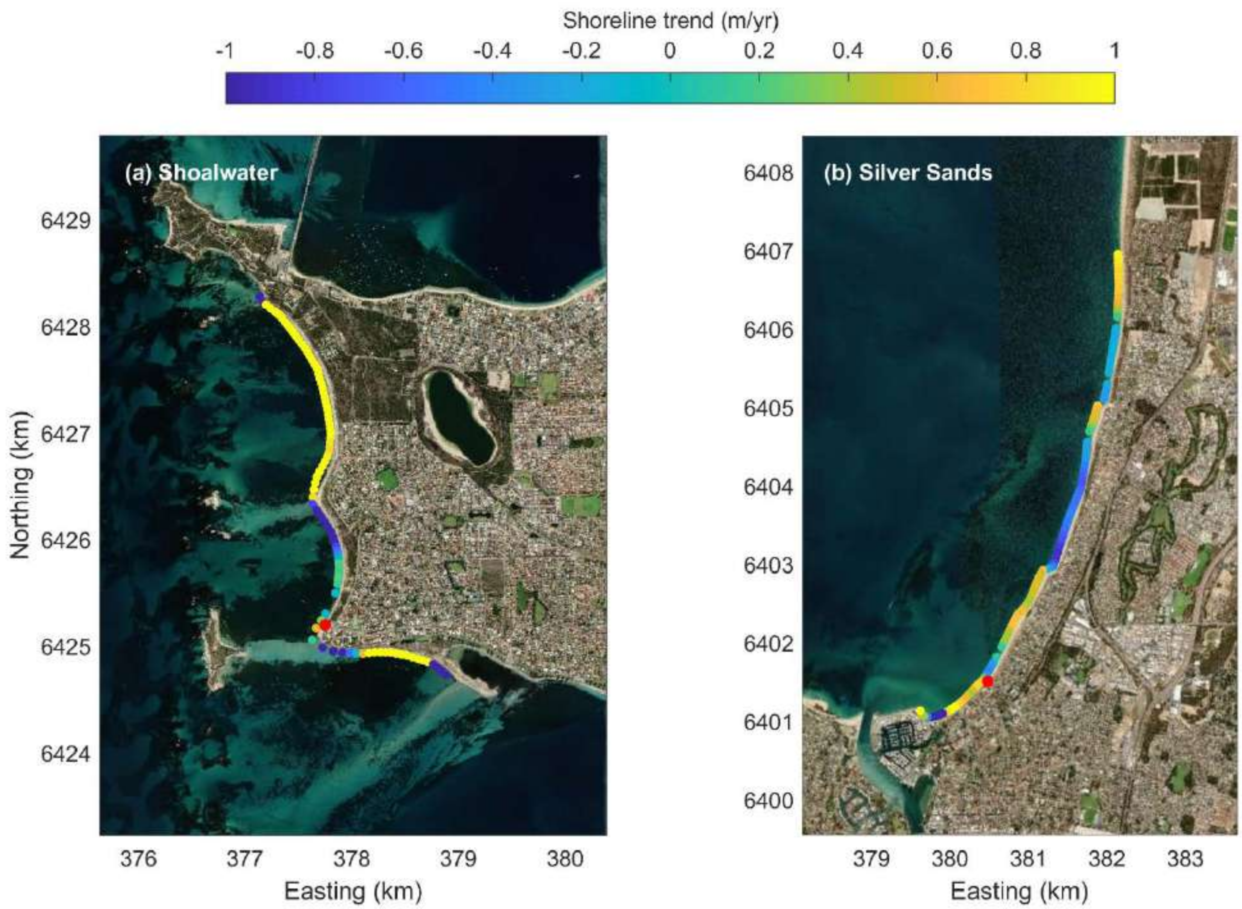


Figure 12. Linear regression rate of shoreline change (August 1986 – December 2019) at (a) Shoalwater Bay and (b) Silver Sands. Positive denotes accretion, negative denotes erosion. Data is only shown for transects where the was a significant linear trend (at the 95% confidence interval). Red 'dot' indicates CoastSnapWA site in each panel.

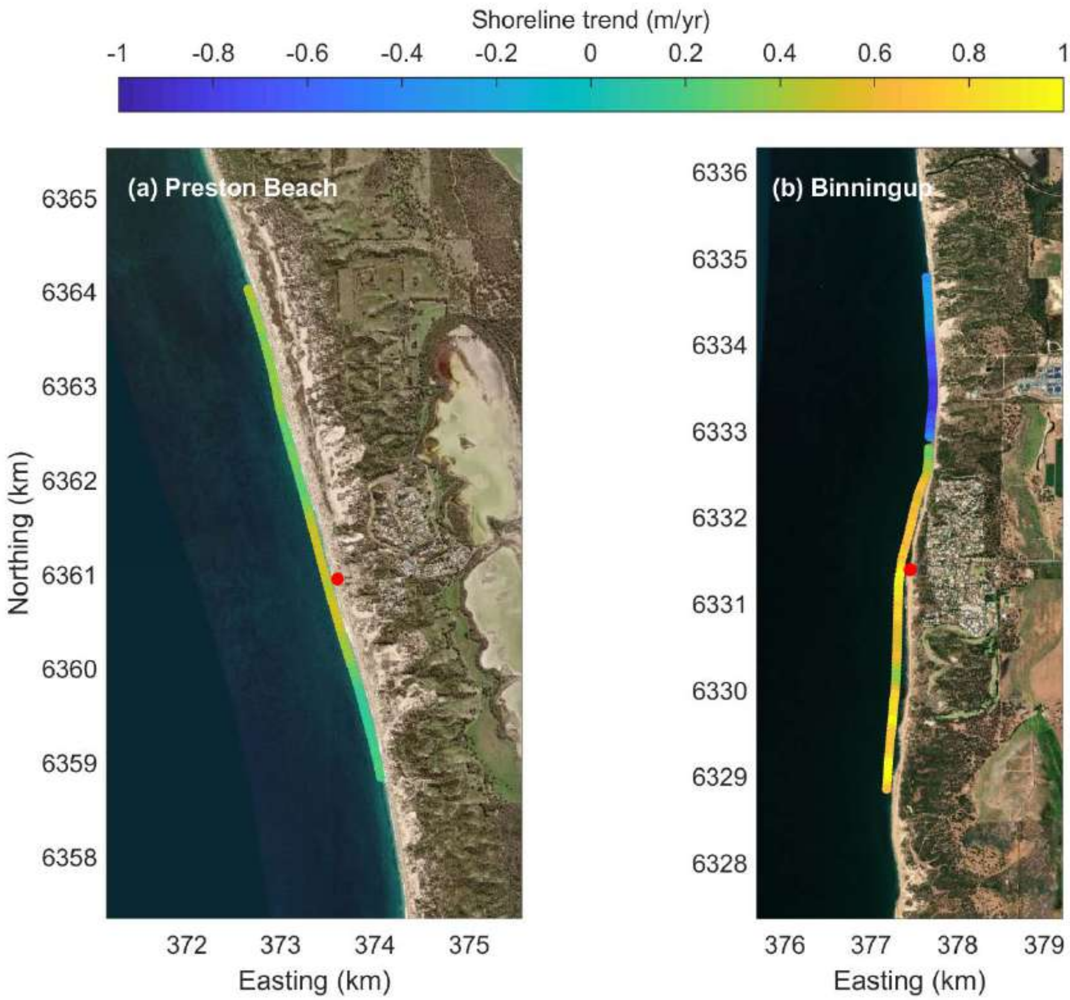


Figure 13. Linear regression rate of shoreline change (August 1986 – December 2019) at (a) Preston Beach and (b) Binningup. Positive denotes accretion, negative denotes erosion. Data is only shown for transects where the was a significant linear trend (at the 95% confidence interval). Red 'dot' indicates CoastSnapWA site in each panel.

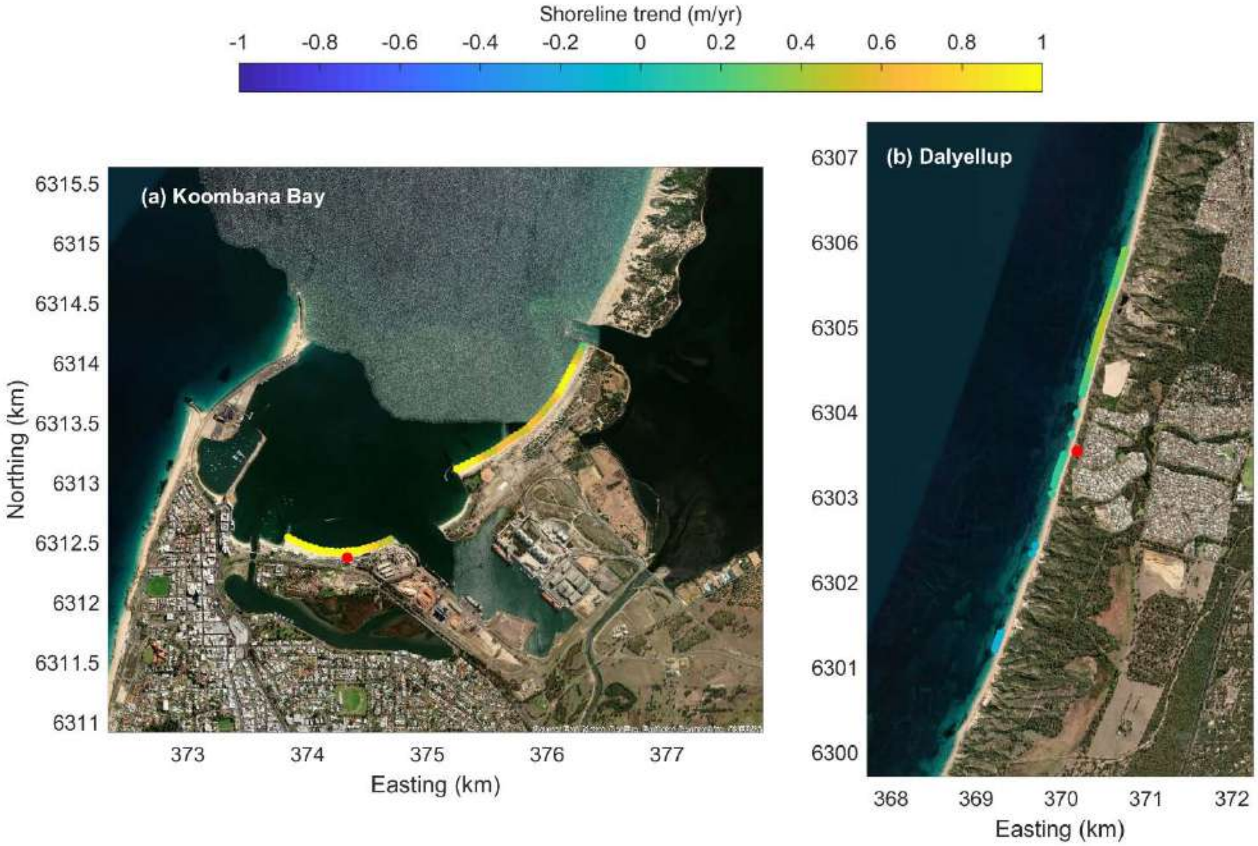


Figure 14. Linear regression rate of shoreline change (August 1986 – December 2019) at (a) Koombana Bay and (b) Dalyellup. Positive denotes accretion, negative denotes erosion. Data is only shown for transects where the was a significant linear trend (at the 95% confidence interval). Red 'dot' indicates CoastSnapWA site in each panel.

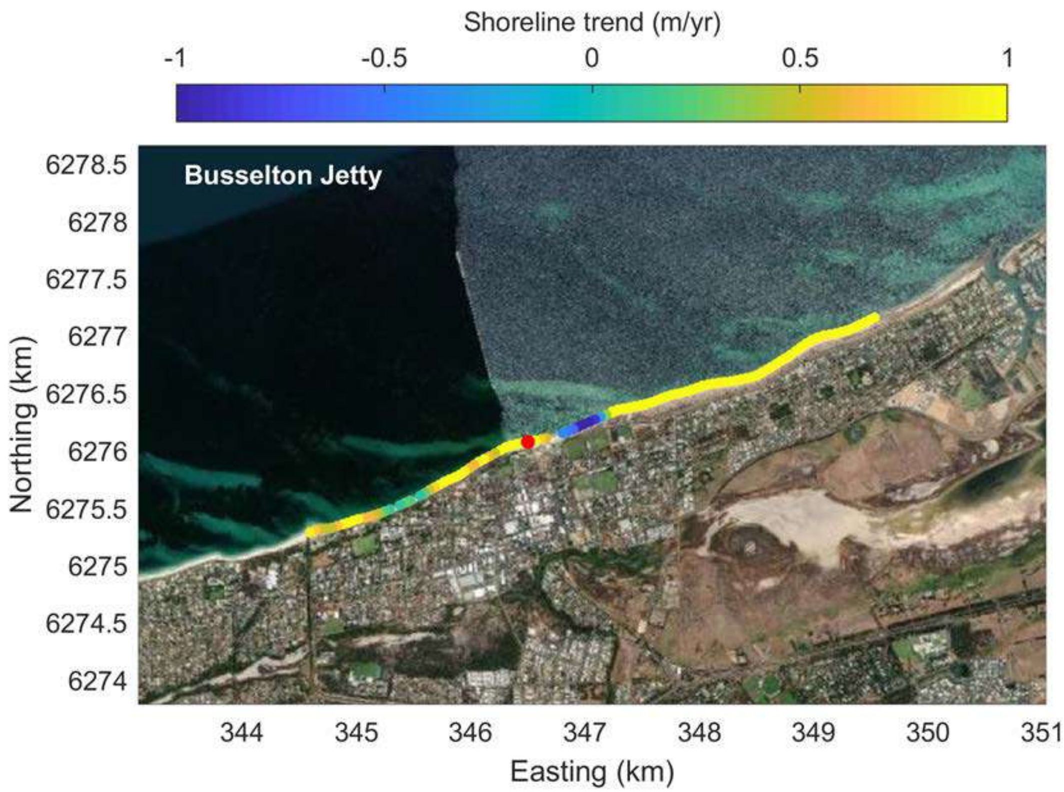


Figure 15. Linear regression rate of shoreline change (August 1986 – December 2019) at Busselton Jetty. Positive denotes accretion, negative denotes erosion. Data is only shown for transects where the was a significant linear trend (at the 95% confidence interval). Red 'dot' indicates CoastSnapWA site.

The satellite-derived shoreline positions showed good agreement with the long-term patterns of shoreline change derived from the WA DoT's coastal movements dataset (Figure 16). This provides a useful comparison for highlighting the temporal scale of variability that both methods can capture. For example, the higher temporal frequency of observations from satellites allows for monthly to decadal processes to be resolved, whereas the vegetation line dataset captures the inter-annual to inter-decadal coastal processes (Figure 16). Furthermore, the agreement in the long-term shoreline dynamics between the two methods highlights the potential for satellite-derived shorelines to complement the coastal movements dataset, particularly in areas that have few vegetation lines mapped (e.g. Dalyellup, Preston Beach).

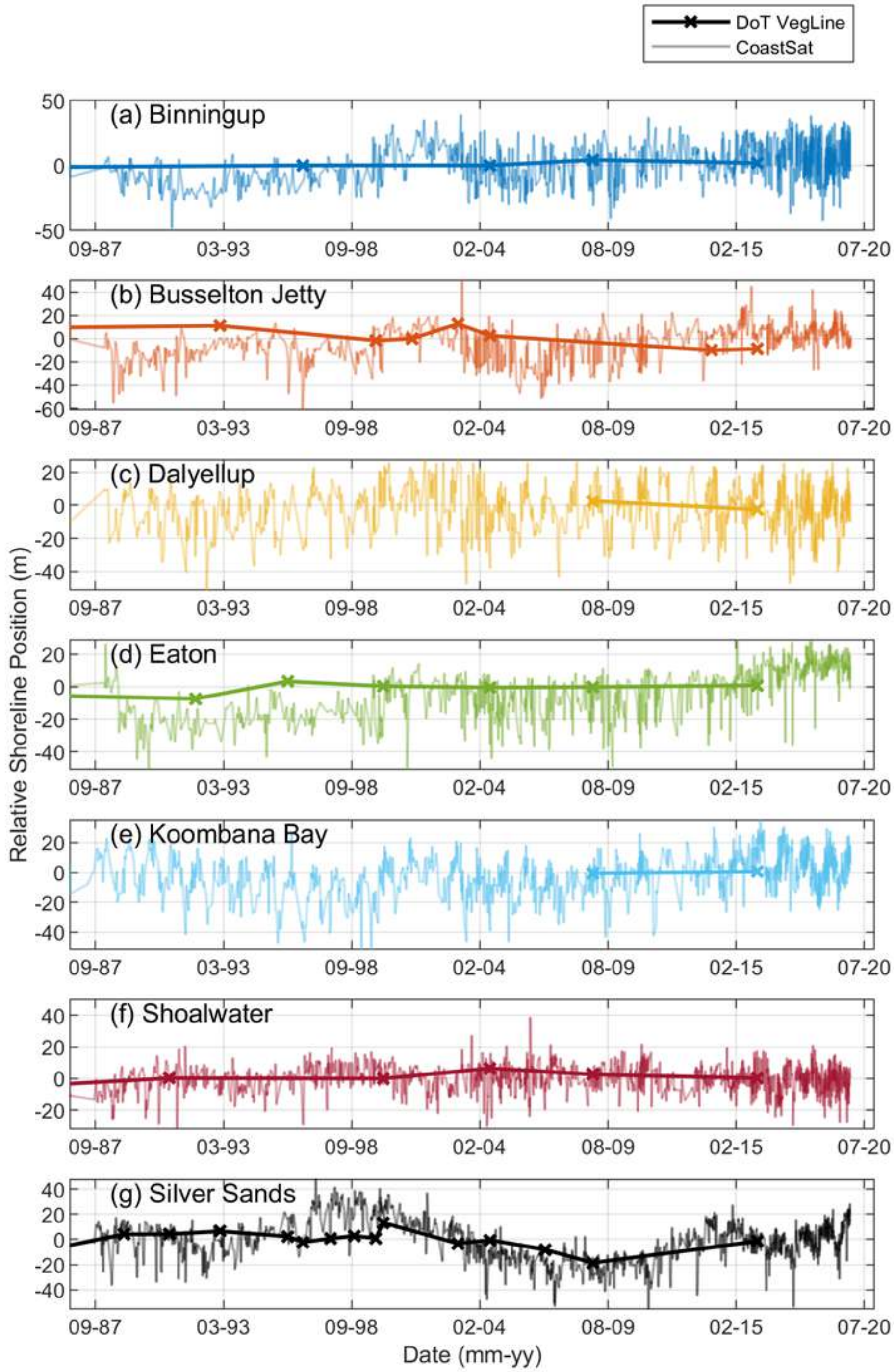
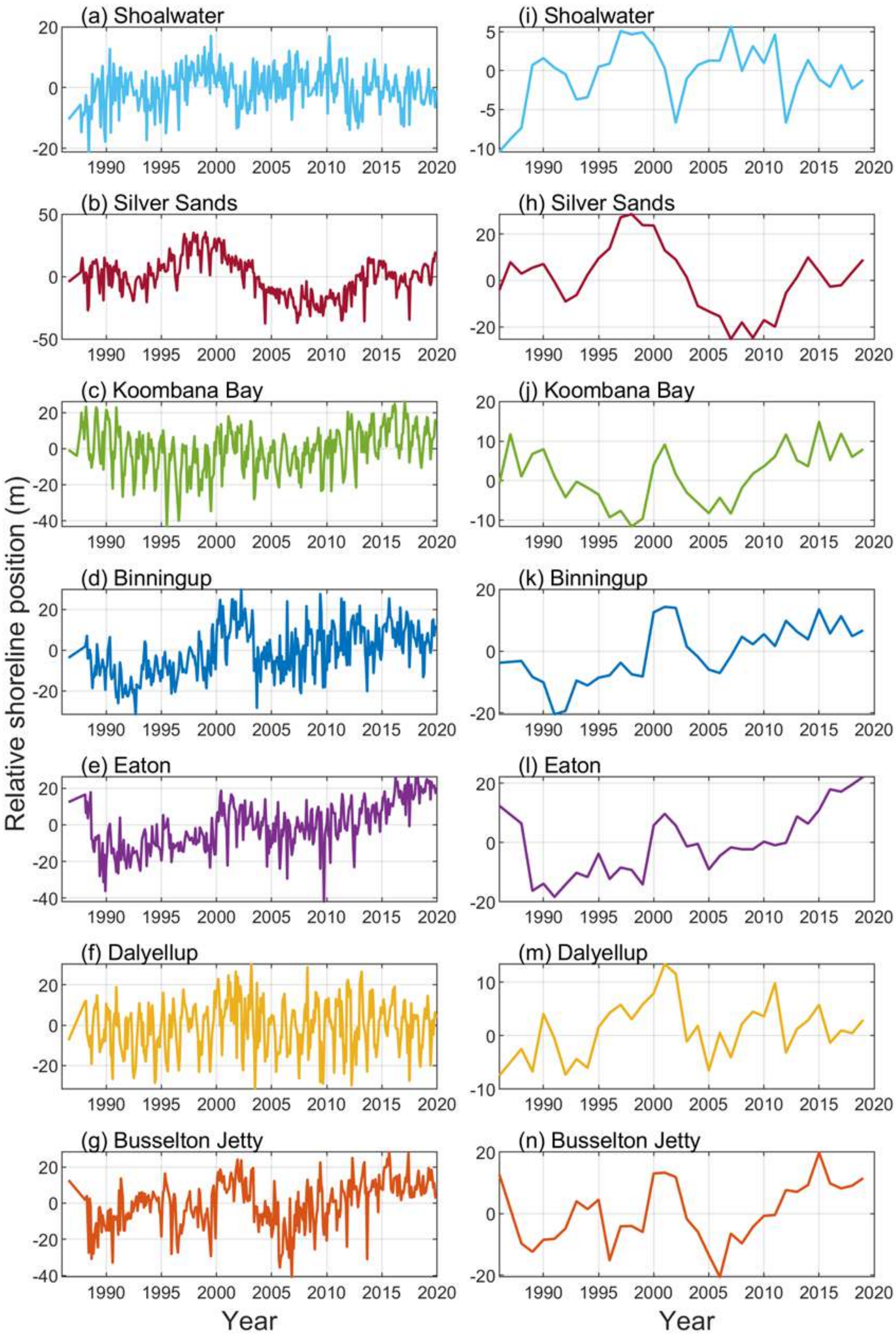


Figure 16. Historical shoreline position from aerial ('x-') and satellite imagery. The shoreline positions from aerial imagery were derived from the vegetation line feature within the WA DoT's coastal movements dataset. Shoreline positions were calculated relative to the median for each dataset.

The satellite-derived shorelines exhibit clear variability in shoreline position across a range of timescales (Figure 16 and 17). The high frequency oscillations in shoreline position represent the typical annual cycle of Western Australian beaches: wider beaches in summer and narrower beaches in winter (Figure 17). Interestingly, there is also a lower frequency signal within the time-series that corresponds to the interannual variability in shoreline position. The interannual variability in shoreline position appears to be regionally-coherent (Figure 17). For example, both Shoalwater Bay and Silver Sands show positive shoreline anomalies around the year 2000, with this peak being evident slightly later in the record for Preston Beach, Binningup, Koombana Bay, and Dalyellup (Figure 17). The regional coherence in shoreline response suggests a consistent driver of shoreline change across the sites (e.g. wave or water level anomalies). However, resolving the drivers of these regional-scale, interannual dynamics requires further investigation (e.g., Cuttler et al., 2020) as well as consideration of the timing of artificial intervention (e.g. sand bypassing). More generally, these data present an opportunity to examine the response of shoreline position to interannual variations in physical processes (e.g., waves, water levels). For example, both wave climate and water levels along Western Australia vary across interannual timescales in response to larger-scale climate oscillations (e.g., El Niño Southern Oscillation, the Southern Annular Mode), which can drive corresponding shoreline changes (Segura et al., 2018). Given the relatively large fluctuations in water level that WA experiences on interannual timescales (e.g. 10 cm), examining historical shoreline response can provide critical data for understanding how shoreline will evolve in the future.



(a) Shoalwater
(b) Silver Sands
(c) Koombana Bay
(d) Binningup
(e) Eaton
(f) Dalyellup
(g) Busselton Jetty
(i) Shoalwater
(h) Silver Sands
(j) Koombana Bay
(k) Binningup
(l) Eaton
(m) Dalyellup
(n) Busselton Jetty
Relative shoreline position (m)
Year
Year

Figure 17. Satellite-derived shorelines for a representative transect within the CoastSnap field of view at each CoastSnapWA site. Left-hand column shows monthly-averaged shoreline position from 1986-2020; right-hand column shows the median annual shoreline position for each year.

5. Discussion and conclusions

Establishment of CoastSnapWA within the PNP has engaged the community in coastal monitoring while also providing quantitative data that can be used to inform coastal planning and management and understand the region's coastal dynamics. Although there are other photo monitoring tools that provide community engagement (e.g. Photomon), CoastSnap provides the added benefit of providing imagery that is readily available for quantitative analysis. Furthermore, the use of social media for display of imagery means that community members within users' social networks can also be engaged without additional effort or resources. For example, although the CoastSnapWA Facebook page only has ~100 followers, some of the posts reached over 500 people due to the post being shared by the CoastSnapWA group members. Thus, the underlying networking of the social media platform is likely to not only attract new users, but also help to facilitate the dissemination of results and the engagement of a wider audience. Additionally, the social platform provided by CoastSnapWA presents an opportunity to mobilise community members at regional scales to capture useful coastal monitoring data for specific events. This has been done successfully in New South Wales, where community-sourced imagery has been used to capture the impact of specific large wave events. This will be a key focus for CoastSnapWA moving forward and looking ahead to winter 2021.

There were obvious trends in the number of images per site that are likely related to the 'visibility' of the CoastSnapWA site and program. For example, Koombana Bay received nearly daily imagery due to direct engagement with the Dolphin Discovery Centre and Shoalwater Bay received similarly high numbers of photos due to its location along the Penguin Island jetty. While it is expected that all sites will see an increasing number of uploads during the transition to summer, increased user engagement could be enhanced by public presentations and/or promotion of CoastSnapWA by PNP local governments through social media platforms.

CoastSnapWA provides complementary data to the on-going coastal monitoring programs within the PNP (e.g., monthly beach widths and photo monitoring). In addition, CoastSnapWA provides an opportunity to enhance the temporal resolution of the existing monitoring datasets with possible daily imagery supplied by community members. The increase in temporal resolution could enhance the ability of the PNP regional coastal monitoring program to capture the impact of short-term coastal processes (e.g. storm events). As the CoastSnapWA dataset increases in size (time) a more quantitative comparison of the regional coastal monitoring dataset with CoastSnapWA-derived beach measurements will be possible (e.g. after 1 year) and/or with other similar topographic datasets (e.g. beach surveys). Furthermore, these comparisons could be enhanced by updating the beach slope data for each CoastSnapWA site (e.g. through updated beach profiles, drone or LiDAR surveys). Similarly, the CoastSnapWA data could be compared to site-specific observations of waves and water levels (e.g. collected by Acoustic Wave and Current instruments or similar) to better understand drivers of the observed changes. This analysis would provide insight into the usefulness of building CoastSnapWA into more general coastal monitoring programs around WA.

6. Recommendations

Moving forward, most of the on-going CoastSnapWA cost is associated with the organisation and analysis of the imagery. Most of the preliminary image processing could be achieved by PNP and local government officers with some training by UWA. For example, images are retrieved from the AWS database using a Python code (free software) and Facebook imagery is directly downloaded from the CoastSnapWA Facebook page. The image database is a formatted Excel spreadsheet that can be simply updated with each new photo and the archiving system is a folder structure on a local computer. However, the remaining image processing and analysis requires specialised software (that may be available to PNP and/or local governments). For example, the image registration relies on Adobe Photoshop and the rectification and shoreline mapping requires Matlab. If Adobe software packages were available to either PNP (or local governments), UWA could train PNP and local government officers to do the image registration and process the imagery into timelapse movies. Although the remaining quantitative analysis (shoreline mapping) is run through a GUI, it does require some significant skills with the native program (Matlab) to execute effectively. Again, if the software was obtained by PNP, UWA could facilitate the training in using the CoastSnap GUI. Or, similarly, UWA could continue to be engaged to complete any or all of the CoastSnap workflow.

Finally, there have been recent developments in the global CoastSnap project. In November 2020 the CoastSnap app was released and global website launched (www.coastsnap.com). The CoastSnap app has been designed to facilitate most of the qualitative processing (image registration and timelapse videos) and provide an online platform for users to engage (and potentially supersede the reliance on social media platforms). The app was launched by colleagues at the University of New South Wales (developers of CoastSnap) and UWA is still in on-going discussions to determine how the app would work for WA. For example, there are on-going costs for maintaining the platform and it is unclear how users such as the PNP or local governments could access the imagery for their own archiving and more detailed (quantitative) analysis. The inclusion of CoastSnapWA into the CoastSnap app will remain an on-going discussion between UWA and PNP. Finally, regardless of whether the qualitative imagery is maintained by the PNP under the current system or the app, an external party is still required at this stage to complete the steps for quantitative analysis (e.g. site survey, image processing, shoreline mapping).

7. References

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8. Appendix 1 – Example CoastSnapWA shorelines

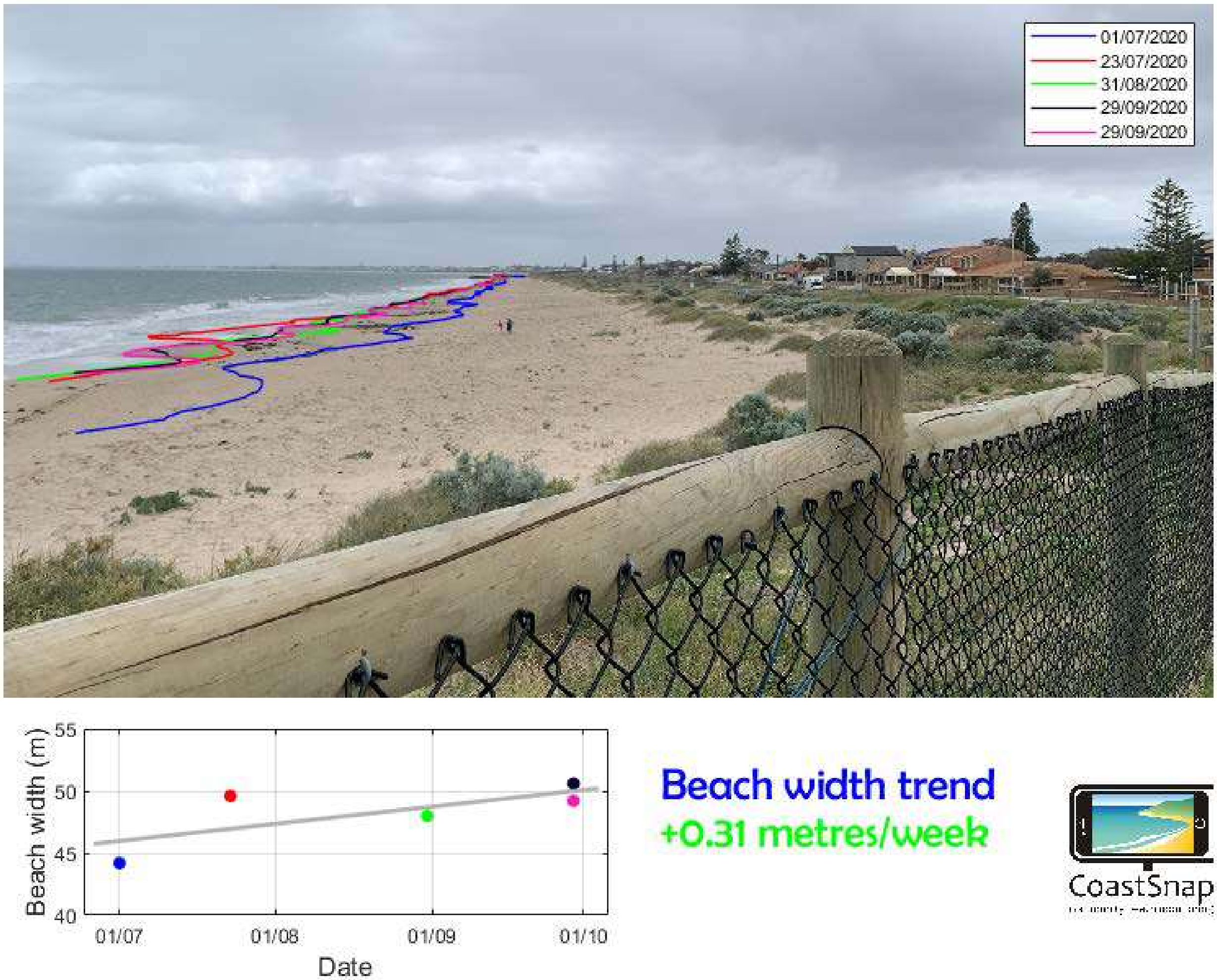

Figure 18. Example shoreline detection at Silver Sands. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach width trend is only calculated over the time period for which shorelines are displayed (01/07/2020 to 29/09/2020).

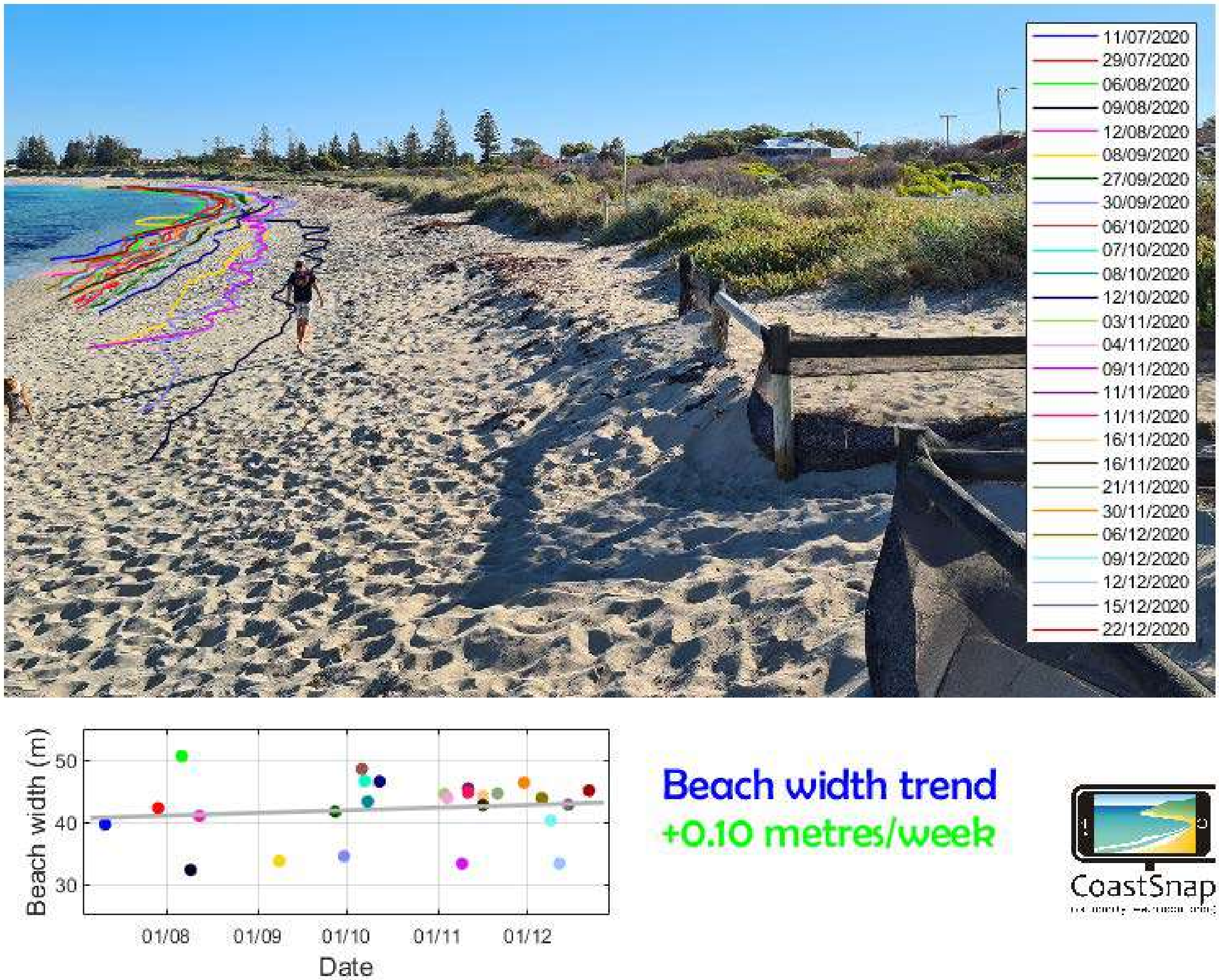

Figure 19. Example shoreline detection at Shoalwater. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach width trend is only calculated over the time period for which shorelines are displayed (11/07/2020 to 22/12/2020).

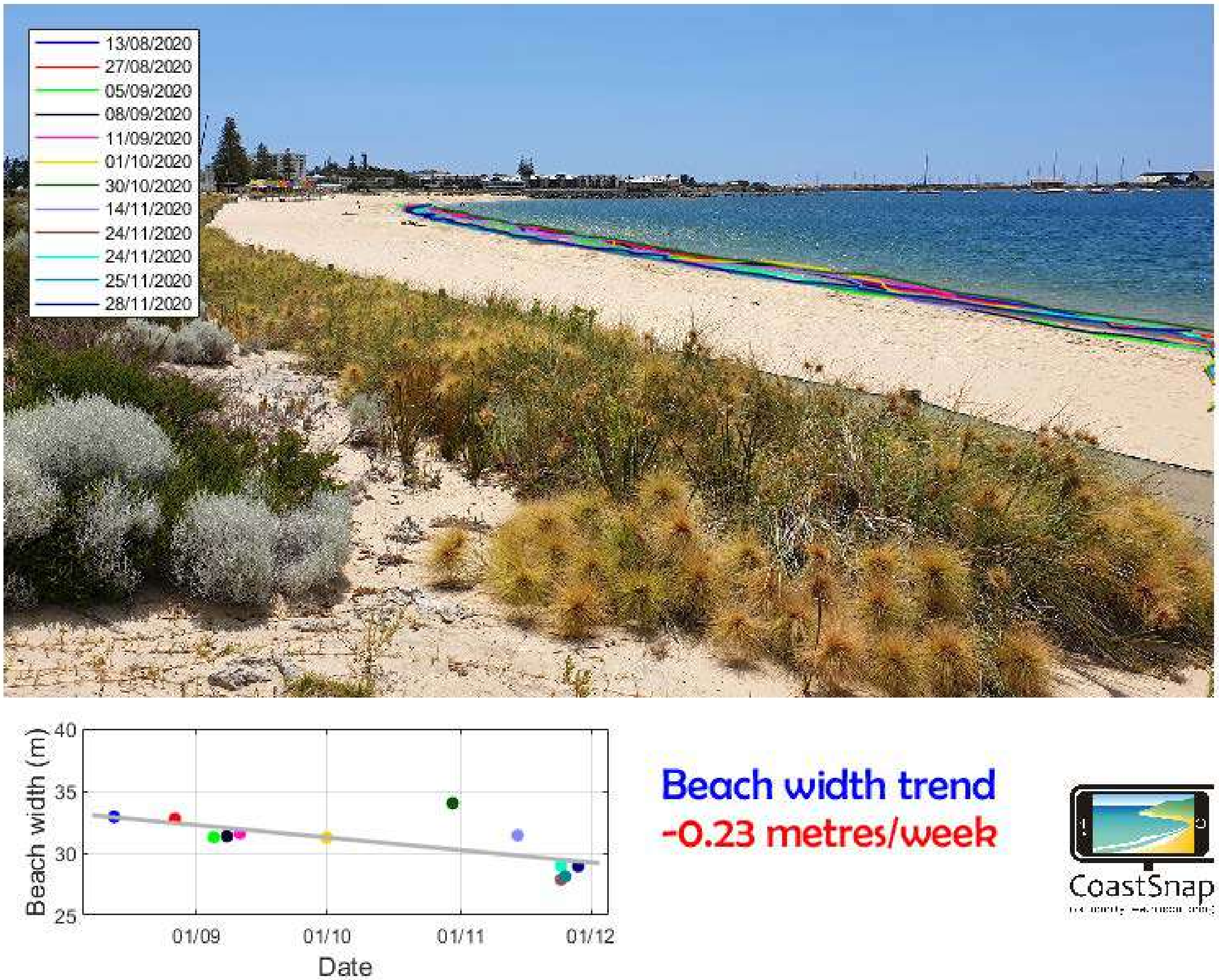

Figure 20. Example shoreline detection at Koombana Bay. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach

width trend is only calculated over the time period for which shorelines are displayed (13/08/2020 to 28/11/2020).

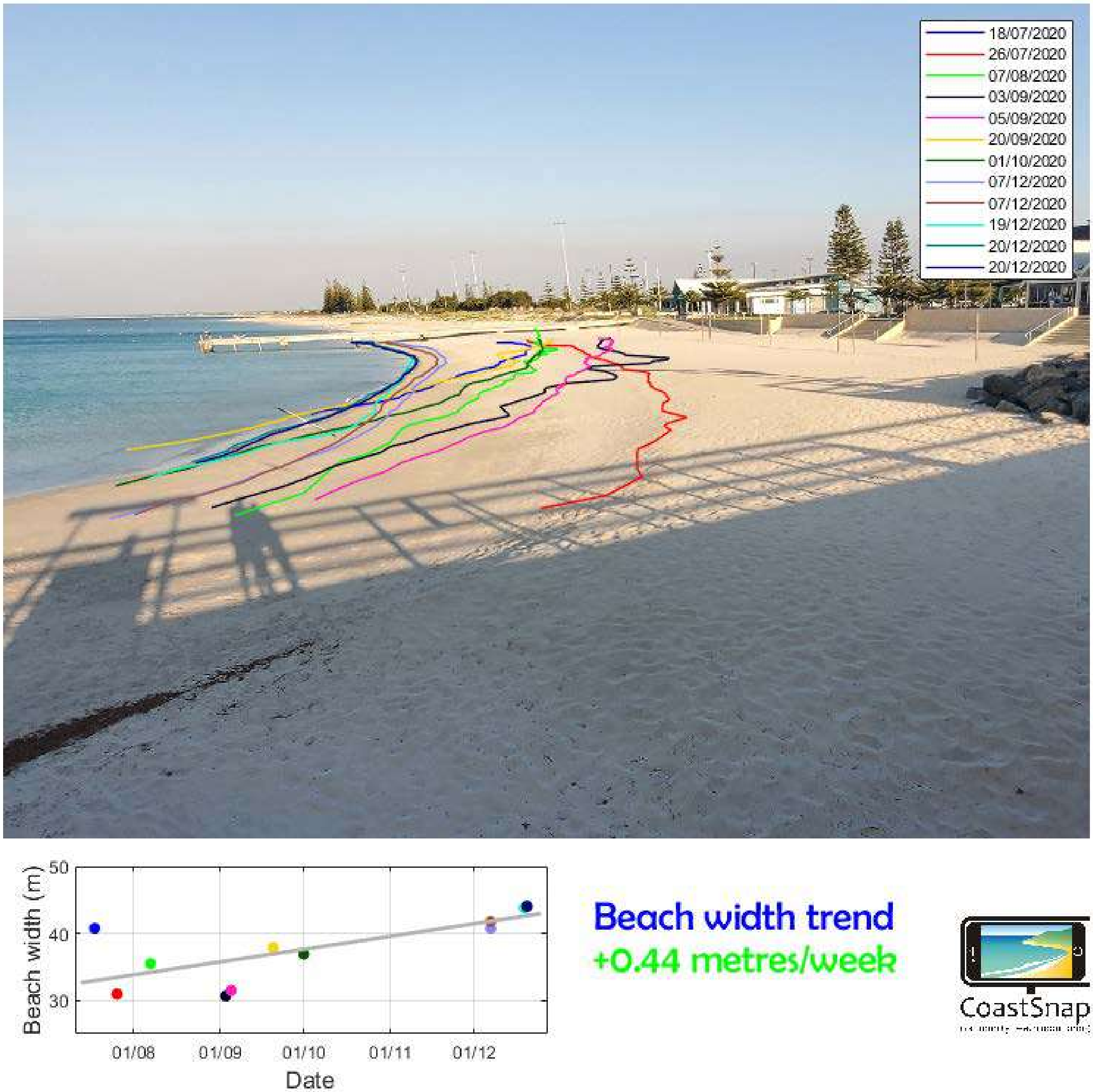

Figure 21. Example shoreline detection at Busselton Jetty. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach width trend is only calculated over the time period for which shorelines are displayed (18/07/2020 to 20/12/2020).

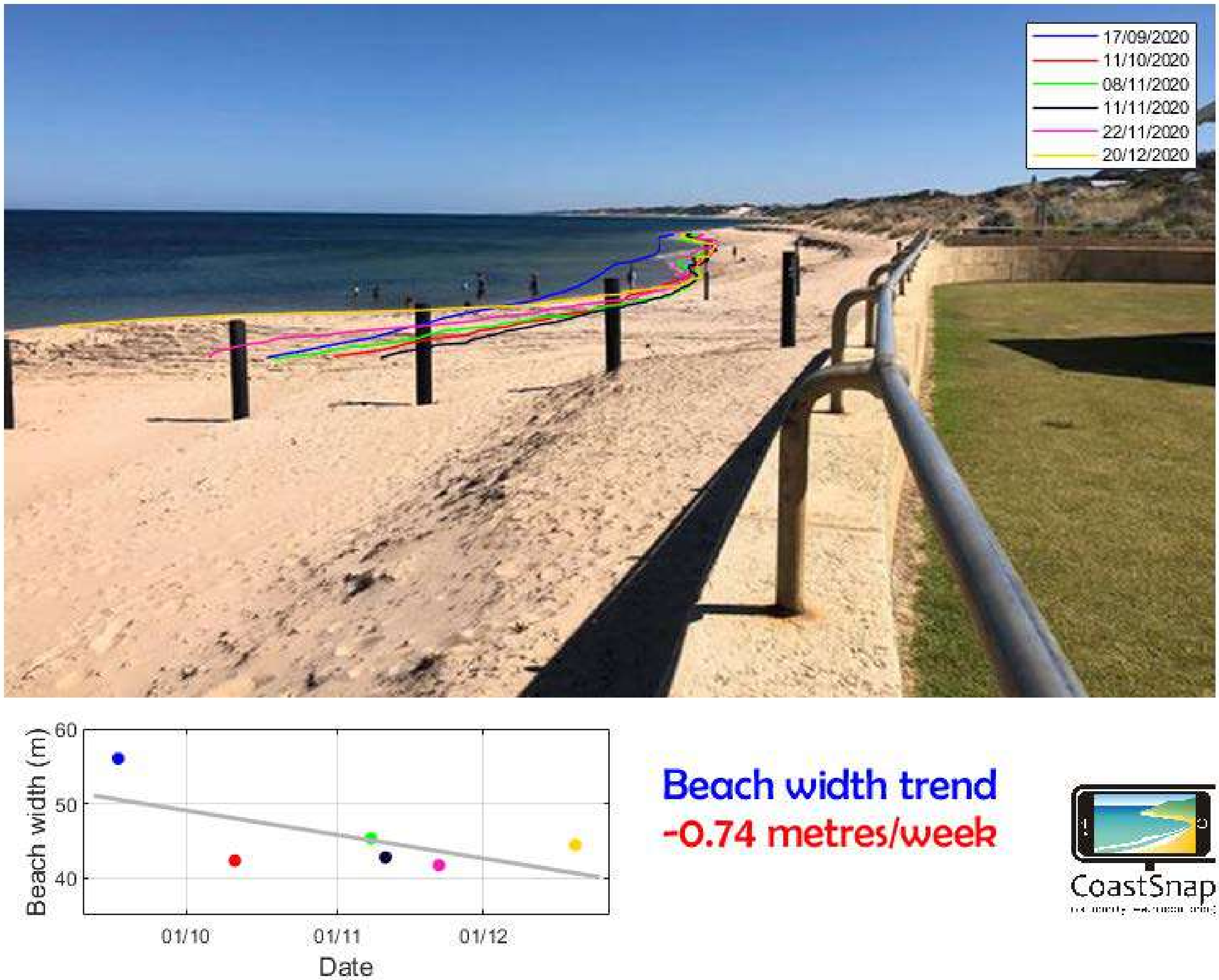

Figure 22. Example shoreline detection at Binningup. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach width trend is only calculated over the time period for which shorelines are displayed (17/09/2020 to 20/12/2020).

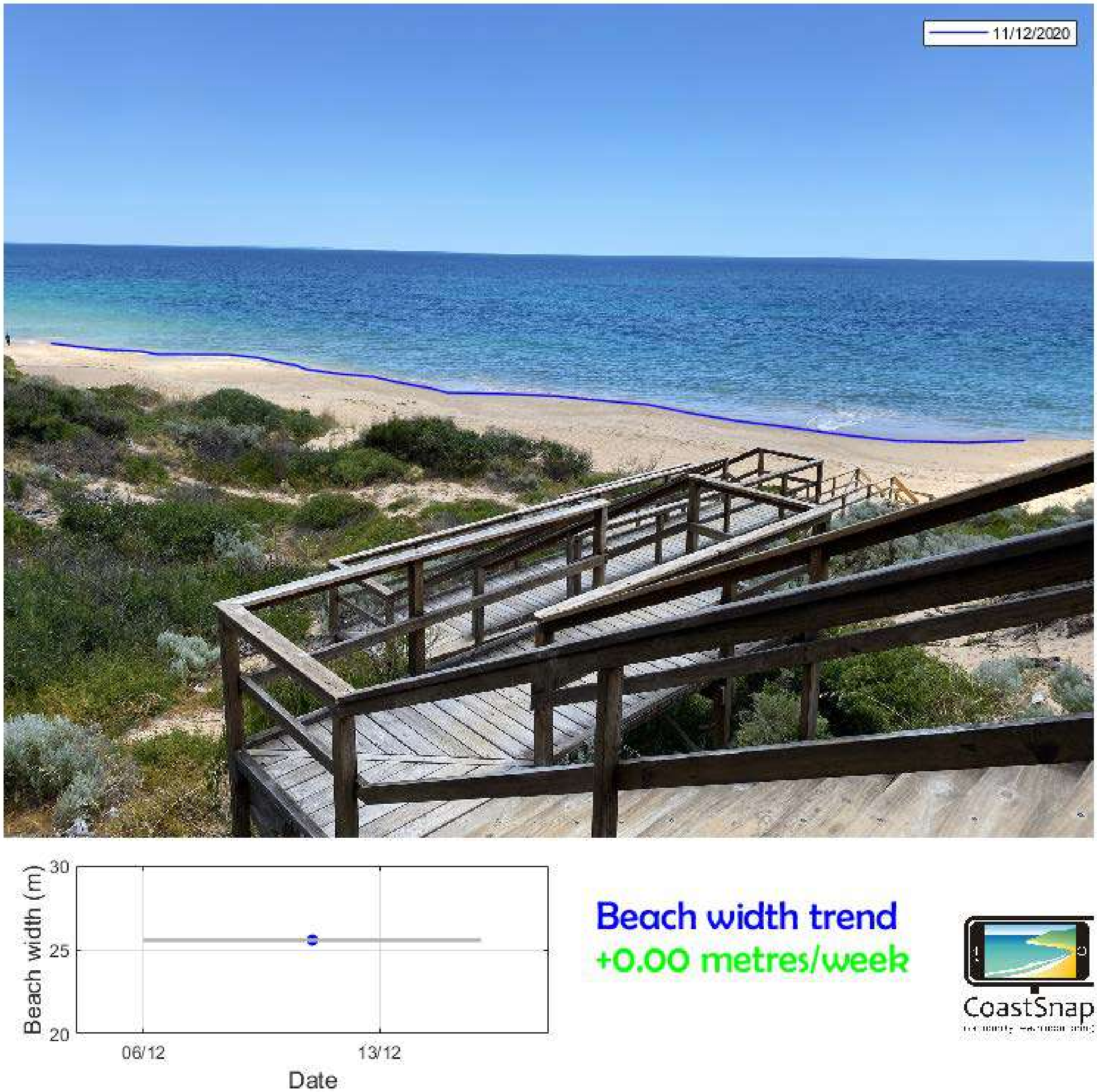

Figure 23. Example shoreline detection at Dalyellup. Note, this was output directly from the CoastSnap GUI and therefore only displays shorelines that were captured at the same stage of tide (±0.05 m). Beach width trend can't be calculated with only one image at the same stage of tide available for Dalyellup as of 27 December 2020.