# DISTANCES WALKED BY BEACH USERS AND PROTECTING SHOREBIRD HABITAT FROM HUMAN RECREATION DISTURBANCE

STEPHEN TOTTERMAN[1]

[1] Empire Vale, NSW 2478, AUSTRALIA.

Email: stephen@totterman.net.au

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## ABSTRACT

Human population growth in coastal south-eastern Australia is increasing development and recreation pressures on beaches and shorebirds. This study observed human recreation on 18 beaches on the far north coast of New South Wales. This region supports the largest numbers of beach resident Australian Pied Oystercatchers *Haematopus longirostris* in the state. The most frequent activities observed were walking (29%), dog walking (21%) and swimming (16%). The mean distance walked along shore was 444 m, which is one order of magnitude greater than mean flight initiation distances for Australian Pied Oystercatchers in preceding studies. Noting that human recreation disturbance is a major conservation threat to beach nesting birds and that pro-environmental behaviour is uncommon among beach users, large separation distances between beach access points and shorebird habitat zones are recommended to reduce human intrusions into those zones. The 95th percentile distance walked was 1683 m, which is a very large separation distance but is consistent with the ecology of beach nesting birds, anecdotal evidence and is supported by the precautionary principle. This spatial zoning and passive human exclusion strategy for managing disturbance to shorebirds could be applied to long and less-developed beaches.

## INTRODUCTION

Beaches are popular areas for human recreation as well as providing habitat for shorebirds. Growing human populations in south-eastern Australia and demand for coastal lifestyles away from the major cities (the “sea change” phenomenon) are strong demographic forces that are increasing development and recreation pressures on beaches and shorebirds (Priest, Straw & Weston 2002). Birdlife Australia have

stated that the greatest conservation threat to beach nesting birds, several of which are currently global/federal/state listed threatened species, is disturbance from people visiting the beach (http://www.birdlife.org.au/projects/beach-nesting-birds).

Birds typically respond to a perceived threat, such as a potential predator or a human, by moving away from the stimulus. Human recreation disturbance rates on beaches often outnumber natural disturbances, even on beaches with low visitation rates (*e.g.* Harrison 2009). Frequent human recreation disturbance can result in displacement of shorebirds from their preferred habitat (*e.g.* Schultz & Stock 1993, Liley & Sutherland 2007), increased energy expenditure in flight responses (*e.g.* West *et al.* 2002), reduced energy intake through disrupted foraging (*e.g.* Burger 1994, West *et al.* 2002) and exposure of eggs or dependent young to diminished parental care (*e.g.* Lord *et al.* 2001, Verhulst *et al.* 2001, Harrison 2009). Disturbance has the potential to result in declines in bird populations over the long term (*i.e.* over a number of generations) if displacement becomes permanent and there is little surplus habitat to move into, if survival is reduced or if breeding productivity is lowered (Gill *et al.* 2001). However, it is difficult to extrapolate observed individual or local effects to population impacts (Davidson & Rothwell 1993, Hill *et al.* 1997, Gill *et al.* 2001).

Manfredo and Dayer (2004) recognised that the thoughts and actions of humans ultimately determine the course and resolution of human-wildlife conflicts. Practical research into human recreation disturbance of wildlife must then include studies of human behaviour (*e.g.* Antos *et al.* 2007). However, far more studies into human disturbance of birds have simply measured flight initiation distances (FIDs), *i.e.* the distance at which an individual bird or flock moves away from a stimulus (typically a human walking towards the focal bird or flock) (see Weston *et al.* 2012a for a summary). A common application for FID data is for selecting “buffer distances” between humans and wildlife. However, Hill *et al.* (1997) cautioned that there are potentially many experimental variables that affect FIDs (*e.g.* species identity, individuals or flocks, breeders or non-breeders, habitat, activity of the birds prior to disturbance, stimulus applied, starting distance, *etc.*) and that the results of any one study are often limited to a narrow set of experimental conditions. There is a risk that end users may generalise and misapply FIDs when developing management plans for human-wildlife conflicts.

It has often been assumed that people will voluntarily adjust their behaviour to maintain appropriate "buffer distances" to avoid disturbing wildlife. However, evidence is growing that such "pro-environmental" behaviour is uncommon in the coastal zone and that non-compliance with regulations and codes of conduct is common (*e.g.* Dowling & Weston 1999, Antos *et al.* 2007, Weston *et al.* 2014). Glover *et al.* (2011) surveyed 295 visitors and residents at Western Port Bay, Victoria, which is listed under the Ramsar convention, and reported that while 86% of respondents supported protection of shorebird habitat, only 39% were supportive of limitations on access for walkers to avoid disturbance of wildlife. For the reasons outlined above, the application of FID data for shorebirds on beaches may be limited to designing human exclosures around individual nest sites or colonies and shorebird roosts (*e.g.* Weston *et al.* 2012, Lafferty *et al.* 2006). Following Hill *et al.* (1997), data on locations of access points and shorebird habitat, visitation rates and distances covered by beach users can be used to estimate the frequency of disturbance to shorebirds and develop management strategies. Large separation distances between access points and shorebird habitat zones (*i.e.* greater than the distances people typically walk) can reduce intrusion rates into those zones and disturbance to shorebirds (Dowling & Weston 1999, Antos *et al.* 2007, Liley & Sutherland 2007).

This study observed distances walked for beach users on the far north coast of NSW. This region supports the largest numbers of beach resident Australian Pied Oystercatchers *Haematopus longirostris* in the state including the South Ballina Beach, Broadwater Beach, Bombing Range Beach and Yuraygir Key Management Sites currently recognised by the NSW Department of Planning, Industry and Environment (https://www.environment.nsw.gov.au/savingourspeciesapp/ViewFile.aspx?ReportProjectID=27). The Australian Pied Oystercatcher is currently listed as Endangered in NSW (https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10386). Preceding studies for the species have reported mean flight initiation distances between 39–129 m (Table 1). This study was motivated by concerns that oystercatchers at South Ballina are increasingly threatened by "beach house" developments and associated human recreation disturbance and that misapplication of FID data is resulting in inadequate separation distances between new beach accesses and oystercatcher territories.

## METHODS

### Study sites

Twenty locations (sites) were sampled on 18 beaches between Tweed Heads and Coffs Harbour, NSW, between 8 February and 24 March 2019 (Figure 1, Table 2). A number of oystercatcher breeding beaches were included. Most beaches were moderate to long (mean length 6.5 km). On shorter beaches, such as Chinaman's Beach (length 0.8 km), walking distances are constrained by the beach length.

Sites were selected to include varying land uses and dogs permitted and dogs prohibited zones (Table 2). Several sites had a number of closely spaced access points that were observed together as one site. The mean between-site distance of 87.7 km was far greater than, for sites with multiple access points, the mean within-site distance of 353 m. Remote and infrequently used sites were not sampled. For example, the picnic area north of Broadwater Headland (at the southern end of South Ballina Beach) was investigated but pedestrian traffic at this site was too infrequent to persevere with sampling.

### Observations

Sampling occurred in the morning and on any day of the week. Ten observations of beach users were made at each site. The grand total was 200 observations (20 sites × 10 observations per site).

Access points were observed from the beach and are defined as the location where an access track arrives onto the beach. For busy access points, every third person/group was observed, counting from when the observer was within sight of the access point and ready to record data. For less busy beaches or at less busy times, accumulation of observations was accelerated by observing every consecutive person/group and/or observing multiple access points. A few sites (*e.g.* South Ballina) were sampled on multiple occasions in order to accumulate ten observations.

The response variable was the maximum one-way distance a focal person/group walked from an access point. Distances were measured using a handheld Global Positioning System (GPS) satellite receiver (Garmin GPSmap 62s) or estimated if less than *c.* 50 m (where GPS imprecision is large relative to the distance to be measured). Distances were measured in the along shore direction and included zero distances where the person/group did not move along shore from the access point (*e.g.* walking directly

down shore to the water). Focal persons/groups were observed discreetly from some distance to avoid disturbing them and thereby potentially affecting their behaviour. Binoculars were used as a visual aid and, on longer beaches, a bicycle was used (at low tide) to quickly move between observation points.

Potential predictor variables recorded together with each focal person/group observation were: day, time the person/group entered the beach (Australian Eastern Standard Time, *i.e.* without daylight saving), number of adults in the group, number of children in the group, dominant gender of adults in the group (male, female or balanced), number of accompanying dogs, activity of the person/group, count of other people within 500 m of the access (excluding the observer), presence/absence of lifeguards on the beach, nearest tide (high or low), a visual estimate of percent cloud cover, wind speed in five categories (calm, very light, light, moderate, strong) and wind direction (eight cardinal points: N, NE, E, SE *etc*). Daily 9 am temperature (°C) and rainfall (mm) observations from the nearest Australian Bureau of Meteorology weather station (http://www.bom.gov.au/climate/data/index.shtml) were later added to the data table. Other variables recorded were access type (pedestrian, vehicle, combined) and distance to parking (m) for each access point and beach length (km) for each site.

Group composition variables (adults, children, gender, *etc.*) were recorded because they may affect the motivation or capability for walking long distances. Counts of people on the beach were recorded because new arrivals may have to walk some distance to find their own space. Similarly, the presence/absence of lifeguards was recorded because people may have to walk some distance to swim in the patrolled zone. Tide was recorded because the hard intertidal zone sand at low tide can facilitate walking longer distances. Weather variables were recorded because uncomfortable conditions can deter walking long distances. Time of day was recorded because it is related to weather conditions and because some persons would have been walking early before work with limited time. Week day was recorded because some persons may have spent more time on beach recreation on weekends. Distance to parking was recorded because it could affect the motivation or capability for additional walking along the beach. Access type was disregarded because there was little variation for this variable (96% pedestrian access points).

All 10 activities recorded are described in Table 3. Only activities that involved walking onto and along the beach were recorded. Joggers, runners, cyclists and horse riders were not included in this study

because, even though they tend to cover longer distances than walkers, those activities were generally uncommon. Four-wheel drives (4WDs) were not part of this study and beach driving was permitted on only seven of the 18 study beaches.

**Statistical analysis**

Conditional inference regression trees (Hothorn *et al.* 2006) were used to discover relationships between distance walked and predictor variables and build predictive models. Regression trees are a machine learning method that explains variation in a single variable by repeatedly splitting the data into homogenous groups using combinations of predictor variables (De'ath and Fabricius 2000). Conditional inference trees utilize statistical tests to avoid variable selection bias and overfitting in conventional tree methods.

Evaluation of machine learning models concerns the ability of models to predict new or withheld data rather than goodness of fit for a single model fitted to the all of the data. A "useful" model is one that can make acceptably accurate predictions for new data. Accuracy (square Root Mean Squared Error; *RMSE*) of distance walked predictions was evaluated using five-fold cross-validation with ten repeats. Relative performance of regression tree models was compared to a mean distance walked null model and is reported as the reduction in cross-validated deviance: $D^2 = (MSE_{null} - MSE_{fitted}) / MSE_{null}$ (Guisan & Zimmerman 2000).

The statistical analysis was performed in R version 3.5.2 (R Core Team 2018) and using the R packages *party* version 1.3-1 (Hothorn *et al.* 2018) and *caret* version 6.0-81 (Kuhn *et al.* 2018). Multiplicity adjusted *P*-values for conditional inference trees were computed using Monte Carlo permutation tests (with 9999 resamples), the minimum number of observations in a terminal node ('leaf') was set to 10 (5% of the sample size $n = 200$) and the minimum sum of numbers of observations in a node in order to be considered for splitting was set to 30 ($3 \times 10$).

**RESULTS**

Observations were nearly equally distributed between weekdays (51%) and weekends (49%) and high (43%) and low tides (57%). Adults were present in 98% of observations and the mean group size was 1.4

adults. There were no school holidays during the survey period. The dataset was nearly uniformly distributed among majority female (32%), male (38%) and balanced gender (30%) groups. Surveys occurred during a dry period (mean rainfall 2 mm on sampling days). Mean 9am temperature was 25°C, mean cloud cover was 30% and wind speed was most frequently light.

The most frequent activities observed were walking (29%), dog walking (21%) and swimming (16%). The distribution of distances people walked had a strong positive skew (Figure 2). The mean distance was 444 m ($n$ = 200; 95% CI = 365–523 m) and the 95th percentile distance (Weston *et al.* 2012) was 1683 m, meaning that five per cent of individuals/groups walked further than that distance. Walkers, unsurprisingly, covered the longest distances compared to other activities (Figure 3). Mean distances walked were similar for walkers with or without dogs at 748 m ($n$ = 41; 95% CI = 605–892 m) and 851 m ($n$ = 58; 95% CI = 667–1035 m) respectively. This comparison indicates that a dog's master controls the distance walked. For both walking activities combined, the mean distance was 809 m ($n$ = 99; 95% CI = 687–930 m) and the 95th percentile distance was 1990 m.

A conditional inference regression tree model with minimum criterion 0.95 (1 – $P$-value) indicated that longer distances were associated with walking activities ($P < 0.001$) and low wind speed (calm or very light winds; $P = 0.048$) (Figure 4). For other activities, distances walked were longer in the middle of the week (Wednesday and Thursday; $P = 0.02$) however there were only 17 observations in that node and this result is not expected to appear in replicate studies. Decreasing the minimum criterion to 0.90 resulted in an additional node which indicated that longer distances were further associated with early mornings (before 06:45 h AET; $P = 0.062$).

Regression trees with minimum criterion 0.95 resulted in a 38% reduction in cross-validated deviance relative to the mean distance walked null model, however the large 443 m residual RMSE indicates large variability in distances walked. Decreasing the minimum criterion to 0.90 did not improve predictive performance ($D^2$ = 36%).

## DISCUSSION

Beach recreation surveys are easy and deliver practical data for management of human recreation. This study sampled a variety of sites and beaches and, while not a probability sample, the results are expected to be representative of beaches in northern NSW. It would be difficult to argue that markedly different results would be obtained from another and perhaps "more representative" sample (*e.g.* simple random sampling). Ultimately, other researchers are encouraged to conduct their own surveys of beach recreation, report those results transparently and let the end users make their own assessments of the quality of such studies.

Walking, with or without dogs, was the most frequent beach recreation activity in this study. Walking has also been reported to be the most frequent activity for other beaches and coastal wetlands in south-eastern Australia (*e.g.* Dowling and Weston 1999, Antos *et al.* 2007, Glover *et al.* 2011) although driving can take over on beaches where 4WDs are permitted (Schlacher *et al.* 2013). Beach driving was not part of this survey although 4WDs can be a serious vector for human recreation disturbance because they enable people to access more remote sections of a beach that could otherwise be refuges for wildlife.

The mean distance that beach users walked in this study was 444 m, which is one order of magnitude greater than mean flight initiation distances for Australian pied oystercatchers in preceding studies (Table 1). Knowing that that pro-environmental behaviour is uncommon for beach users, this result supports the proposal for large separation distances between beach access points and shorebird habitat zones to reduce disturbance to shorebirds (see Introduction).

Selecting an appropriate separation distance depends on visitation rates to the beach. For the simplest case of one shorebird zone and one access point, the intrusion rate (*R)* is:

$$R = V \times [1 - p(d)]$$

where V is the mean visitation rate and *p(d)* is the proportion of beach users walking as far as distance *d*, which is the distance from the access point to the shorebird zone. This formula can be easily extended to account for multiple access points.

Given a maximum tolerable intrusion rate and a visitation rate, the separation distance is estimated from the distribution of distances:

$$p(d) = 1 - R/V$$

This equation explains that, for some fixed intrusion rate *R*, the separation distance (*d*) should be increased as the visitation rate *V* increases. Anticipating future growth in human populations and beach recreation, it should be appropriate to simply adopt the 95th percentile distance under the assumption that patterns of beach recreation and distances walked hold into the future. This result is very simple in comparison to the many conditions for FID results (Hill *et al.* 1997). However, as daily visitation rates increase to hundreds of people or more, the maximum tolerable intrusion rate will eventually be exceeded and other management actions that attempt to promote coexistence between humans and beach nesting birds could be investigated (*e.g.* Lafferty *et al.* 2006, Weston *et al.* 2012, also see the review by Pienkowski 1993). The spatial zoning and passive human exclusion strategy for managing disturbance proposed in this study is more applicable to long and less-developed beaches. Such beaches are also where larger numbers of beach nesting birds can be found (*e.g.* the Australian Pied Oystercatcher Key Management Sites that were noted in the Introduction).

The 95th percentile distance in this study was 1683 m. This result includes dog walkers although Birdlife Australia have recommend that dogs be totally banned from beaches with shorebird habitat (http://www.birdlife.org.au/media/call-for-dog-free-beaches/). A 1683 m separation distance seems extremely large but is consistent with the ecology of beach nesting shorebirds and is supported by anecdotal evidence.

Some species of beach nesting birds occupy linear territories that can be hundreds of metres in length. For example, the maximum recorded oystercatcher breeding density for South Ballina Beach was 18 pairs in 2000 (NSW Department of Planning, Industry and Environment, unpub. data), over c. 18.7 km of available habitat, which is equivalent to a mean territory length of 1040 m. Large separation distances can protect such long breeding territories from human intrusions. Moreover, the large disturbance radius of *c.* 1683 m from this study can help explain why short beaches are often not occupied by beach nesting

shorebirds, for the reason that they are not long enough to provide a refuge from human recreation disturbance.

Nest site location data from 2001–2017 show a 4.3 km gap in the distribution of breeding oystercatchers around the village of Patch's Beach (currently with 19 dwellings) on South Ballina Beach (NSW Department of Planning, Industry and Environment, unpub. data). Harrison (2009) suggested that this gap was the result of permanent and daily human recreation disturbance which deters oystercatchers from occupying otherwise suitable habitat close to Patch's Beach. The equivalent 2150 m disturbance radius (= 0.5 × 4300) is close to the 1683 m 95th percentile distance from this study.

Restricting public access to beaches is socially unacceptable (Glover *et al.* 2011) and politically toxic. Opponents to this management action could argue that the population impacts of human recreation disturbance at individual sites are unproven (Davidson & Rothwell 1993, Hill *et al.* 1997, Gill *et al.* 2001). However, life history and habitat attributes do make beach nesting birds particularly sensitive to human recreation disturbance. Territorial behaviour and high site fidelity of oystercatchers (Taylor *et al.* 2014), for example, means that breeding pairs are unlikely to relocate to any alternative sites, which anyhow could also have high levels of disturbance. Beaches widths are similar to flight initiation distances (Table 1) and shorebirds can find it difficult to maintain a "safe" distance from people in such narrow habitats (Pienkowski 1993, Harrison 2009). Beach nesting bird populations are typically concentrated at a number of Key Management Sites and local changes in breeding populations at those sites are population impacts.

Finally, the NSW Local Government Act 1993 (NSW Government 1993) can provide some support for protection of beach nesting bird habitat. Section 8A of the Act requires that the precautionary principle, as one of the principles of "ecologically sustainable development", is considered in decision-making:

> *(a) the precautionary principle—namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*

However, while Schedule 1 of the NSW Biodiversity Conservation Act 2016 (NSW Government 2016) lists several threatened beach nesting birds, there is a serious oversight in Schedule 4, where human recreation disturbance is not listed as a Key Threatening Process.

Opponents to restricted access to beaches could further argue for alternative management actions that promote coexistence between humans and beach nesting birds and could be a "win-win" compromise solution to this recreation-conservation conflict. However, managing human behaviour is known to be difficult and costly (see Introduction) and so access restrictions are more likely to be effective in conserving populations of beach nesting birds. There are only a small number of long and less-developed beaches in south-eastern Australia where larger numbers of beach nesting birds can still be found and it could be argued that restricting access to beach nesting bird habitat zones on these beaches would not be a severe impost on society as a whole.

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**Table 1.** Mean flight initiation distances (FIDs) for Australian Pied Oystercatchers in preceding studies.

| Reference | Habitat | Stimulus | Mean FID (m) | Breeding status |
|---|---|---|---|---|
| Paton *et al.* 2000 (in Weston *et al*. 2012) | Estuary | Human | 83 | Non-br. |
| Blumstein 2006 | Unknown | Human | 39 ($n$ = 23) | Unknown |
| Harrison 2009 | Beach | Human | 46 ($n$ = 79) | Br. |
| | | Human and dog | 129 ($n$ = 20) | Br. |
| Glover 2011 | Varied | Human | 42 ($n$ = 21) | Non-br. |

**Table 2.** Study sites and beach access points sampled in this study (north to south). Major land uses within 200–300 m of each access point are classified into four categories: R = Residential; P = Public Reserve (typically at 'peri-urban' sites); T = Tourism; C = Conservation. Beaches known to have breeding oystercatchers (OC) are recorded as 'Yes'. Access points where dogs are allowed onto the beach are recorded as 'Yes'.

| Beach | Length (km) | OC | Site | Access | Dogs | Land use | Co-ordinates (S, E) |
|---|---|---|---|---|---|---|---|
| Letitia Spit | 3.3 | | Fingal | Caravan park | Yes | T | 28° 11' 45.6", 153° 33' 59.9" |
| | | | | Fingal SLSC | Yes | R | 28° 11' 47.3", 153° 34' 01.6" |
| Bogangar | 8.6 | | Salt | Salt SLSC | Yes | R | 28° 16' 38.2", 153° 34' 47.6" |
| Cudgera | 2.8 | | Hastings Point | Opp. Shell stn. | Yes | P | 28° 22' 10.1", 153° 34' 30.8" |
| Wooyung | 16.6 | | Potts Point | Bridge | Yes | P | 28° 23' 32.9", 153° 34' 05.2" |
| Wooyung | 16.6 | | Wooyung Corner | Opp. c'van park | Yes | T | 28° 27' 25.0", 153° 33' 14.8" |
| | | | | WOO46 | Yes | T | 28° 27' 26.1", 153° 33' 14.6" |
| | 7.4 | | | Clifford St. | | R | 28° 41' 26.9", 153° 36' 51.3" |
| Tallow | | | Suffolk Park | Caravan park | | T | 28° 41' 29.9", 153° 36' 50.6" |
| | | | | Alcorn St. S. | | R | 28° 41' 31.5", 153° 36' 50.3" |
| Seven Mile | 8.4 | | Lennox Head | Lake Ainsworth | Yes | P | 28° 46' 56.0", 153° 35' 39.3" |
| Angels | 1.7 | | Angels (East Ballina) | Overpass | Yes | P | 28° 50' 57.2", 153° 36' 05.0" |
| | | | | Old 4WD track | Yes | R | 28° 51' 04.8", 153° 36' 01.1" |
| | | | | Car park | Yes | R | 28° 51' 10.8", 153° 35' 57.8" |
| | | | | Angels Beach | Yes | R | 28° 51' 13.5", 153° 35' 56.3" |
| South Ballina | 23.0 | Yes | South Ballina (near c'van park) | Pedestrian | | T, C[1] | 28° 53' 16.1", 153° 34' 21.4" |
| | | | | 4WD | | T, C[1] | 28° 53' 17.8", 153° 34' 19.1" |
| | | | Patchs Beach | Pedestrian | Yes | R | 28° 56' 59.0", 153° 30' 56.6" |
| Airforce | 5.8 | Yes | Evans Head | SLSC | | R | 29° 06' 44.8", 153° 26' 04.3" |
| Chinamans | 0.8 | | Chinamans | Dirrawong Res. | | C | 29° 07' 49.5", 153° 26' 52.3" |
| Ten Mile | 12.5 | Yes | Shark Bay (Bundjalung NP) | 4WD | | C | 29° 21' 31.4", 153° 21' 16.7" |
| | | | | Picnic area | | T, C | 29° 21' 36.2", 153° 21' 34.3" |
| Iluka | 2.7 | | Iluka | Car park | Yes | P | 29° 25' 12.9", 153° 21' 48.3" |
| | | | | Breakwall | Yes | P | 29° 25' 18.0", 153° 21' 46.4" |
| Pippi | 1.7 | | Yamba | Dolphin Park | Yes | R | 29° 26' 40.6", 153° 21' 56.2" |
| | | | | Dolphin Park | Yes | R | 29° 26' 42.2", 153° 21' 55.3" |
| Plumbago | 1.9 | Yes | Lake Arragan camping area (Yuraygir NP) | Picnic area | | T, C | 29° 33' 56.7", 153° 20' 14.6" |
| | | | | Camp | | T, C | 29° 34' 01.6", 153° 20' 14.5" |
| | | | | Camp | | T, C | 29° 34' 05.7", 153° 20' 14.0" |
| | | | | Red Cliff | | T, C | 29° 34' 08.7", 153° 20' 16.4" |
| Illaroo | 9.0 | | Illaroo camping area (Yuraygir NP) | Steps | | T, C | 29° 45' 22.7", 153° 17' 31.3" |
| | | | | Barbeque | | T, C | 29° 45' 25.2", 153° 17' 31.5" |
| | | | | Gully | | T, C | 29° 45' 27.9", 153° 17' 31.6" |
| | | | | Picnic area | | T, C | 29° 45' 32.1", 153° 17' 34.5" |
| Wooli | 6.7 | Yes | Wooli | Scope St. | Yes | R | 29° 51' 47.8", 153° 16' 04.1" |
| | | | | Firth Ln. | Yes | R | 29° 52' 17.9", 153° 15' 58.9" |
| | | | | Water tower | Yes | R | 29° 52' 22.4", 153° 15' 58.6" |
| | | | | Main Beach | Yes | R | 29° 52' 32.2", 153° 15' 58.1" |
| | | | | South Tce. | Yes | P | 29° 52' 47.6", 153° 15' 58.0" |
| Sandy | 1.1 | | Sandy Beach | Car park | | R[2] | 30° 08' 57.2", 153° 12' 00.2" |
| | | | | Park | | R[2] | 30° 09' 04.3", 153° 12' 00.2" |
| | | | | Park | | R[2] | 30° 09' 08.6", 153° 12' 00.8" |
| Sapphire | 2.2 | | Sapphire Beach | Cafe | Yes | T, C[2] | 30° 13' 30.8", 153° 09' 20.8" |
| | | | | Private | Yes | R[2] | 30° 13' 37.8", 153° 09' 17.7" |
| | | | | Caravan park | Yes | T[2] | 30° 13' 45.2", 153° 09' 14.3" |
| | | | | Park | Yes | R[2] | 30° 13' 49.0", 153° 09' 13.7" |
| | | | | Lakeside Dr. | Yes | R[2] | 30° 13' 51.1", 153° 09' 13.3" |

Acronyms: 4WD = four-wheel drive; NP = National Park; SLSC = Surf Life Saving Club

[1] The northern end of South Ballina Beach adjoins the Richmond River Nature Reserve (Conservation) however the major land use near the caravan park is tourism.

[2] Sandy and Sapphire Beaches adjoin the typically narrow Coffs Coast Regional Park (Conservation) and the major land uses around those areas sampled were Residential and Tourism.

**Table 3.** Descriptions of beach recreation activities recorded in this study.

| Activity | Description |
|---|---|
| Walking (WK) | Walking along the beach, usually direct and close to the shoreline. Walkers walk for some distance and then turn back or exit the beach. |
| Dog walking (WD) | Walking along the beach accompanied by one or more dogs, on or off leash. |
| Swimming (SW) | Self-explanatory. Does not include wading. |
| Surfing (SF) | Mostly on surfboards. |
| Picnic (PC) | Picnics generally involved multiple persons and a variety of activities. Features of this activity can include beach shelters, food and drink, recreational equipment and the group stays in one location for an extended period. |
| Sunbathing (SB) | Self-explanatory. |
| Looking (LK) | Viewing the beach or ocean, checking the beach, fishing or surf conditions and often where there is seating on the beachfront. |
| Fishing (FI) | Recreational line fishing. |
| Playing (PL) | Young children playing in the sand. Unlike picnickers, these groups don't bring so much equipment, don't stay long and adults present are supervising and not engaged in other recreation. |
| Photography (PH) | Recreational photography. |

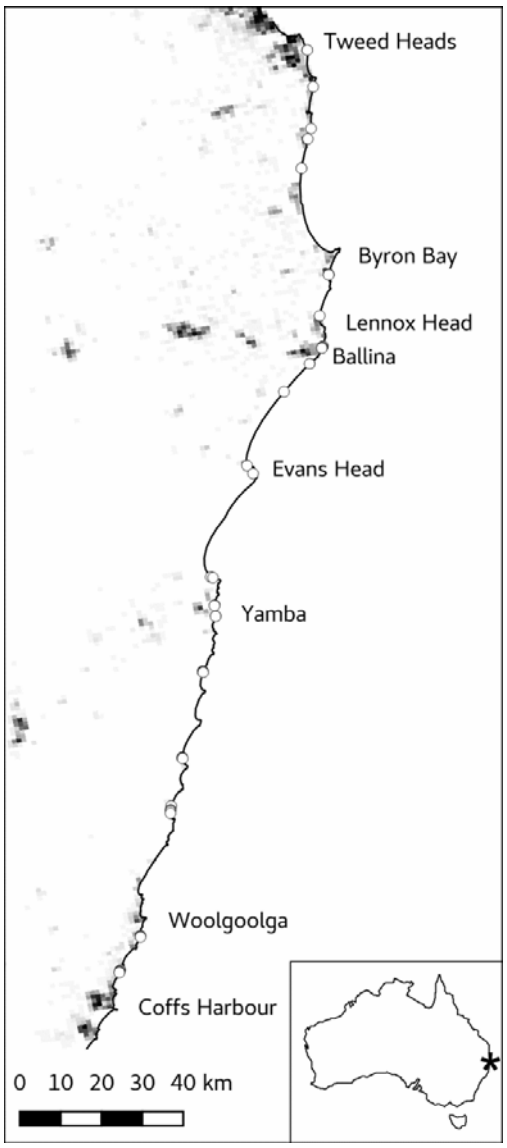


**Figure 1.** Map of the far north coast of New South Wales showing the location of access points (white-filled circles) where beach recreation was studied (see Table 2 for details of beaches and sites). The background image shows human population densities (scale 0–2000 persons.km$^{-2}$) from the Australian Population Grid 2011 (https://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.007). Text annotations identify larger coastal towns and cities. The inset map shows the location of the study region within Australia.

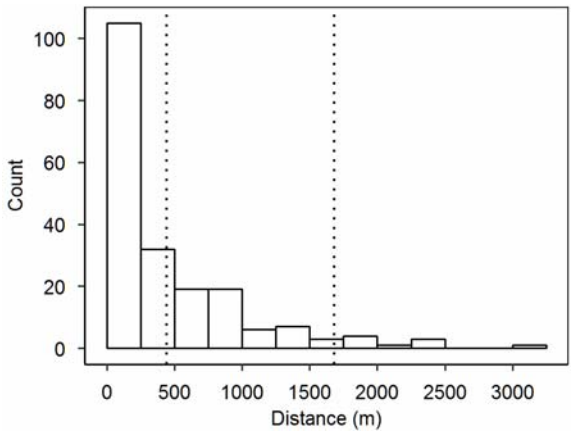


**Figure 2.** Histogram of distances people walked (*n* =200). Vertical dotted lines indicate the mean and 95th percentile distances (444 and 1683 m respectively).

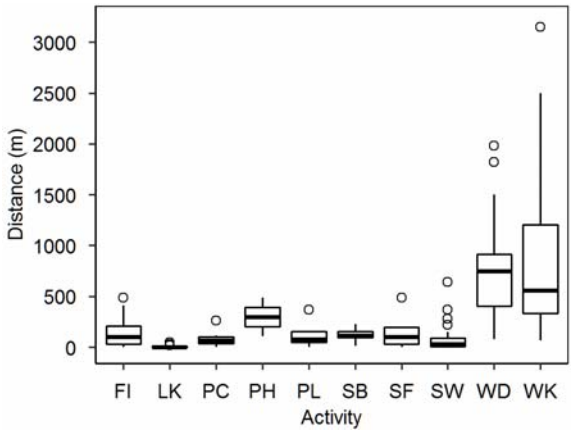


**Figure 3.** Box and whisker plots of distances people walked for each activity: FI =fishing, LK = looking, PC = picnic, PH = photography, PL = playing, SB = sunbathing, SF = surfing, SW = swimming, WD = dog walking, WK = walking. Boxes show the first quartile, median and third quartile, whiskers extend to a maximum of 1.5 times the interquartile range and data outside the whiskers are plotted as individual points (white-filled circles).

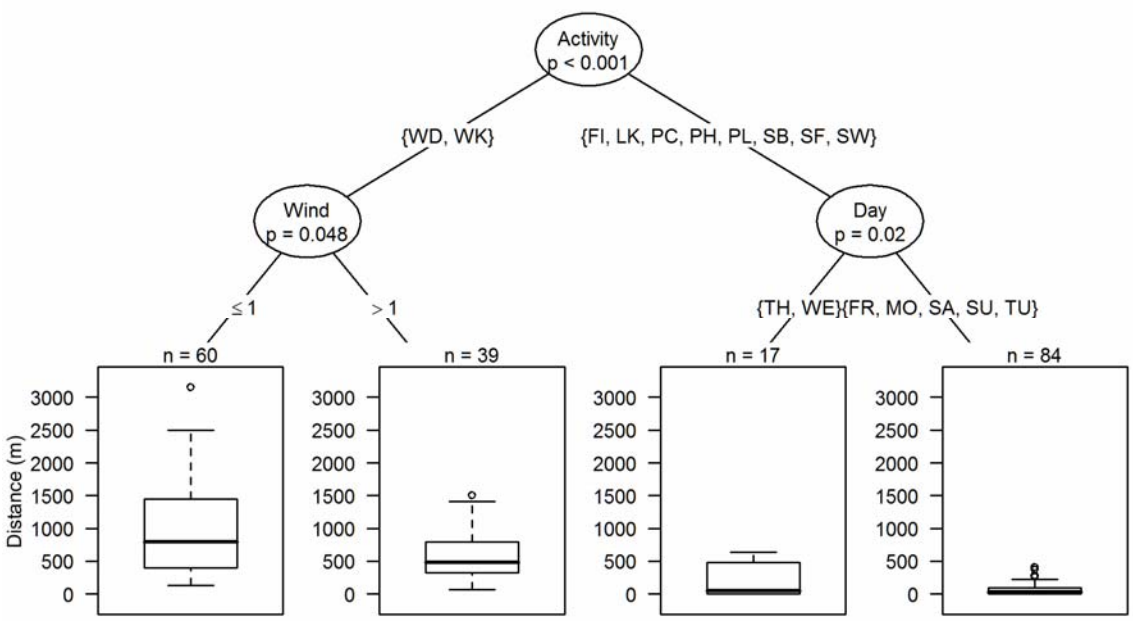


**Figure 4.** Conditional inference regression tree for distances people walked. The left branch indicates that:1) walkers typically covered longer distances than did other beach users (right branch), and 2) distances walked typically decreased at higher wind speeds. Wind speeds ≤ 1 were calm (0) and very light (1).