Urban blue: A global analysis of the factors shaping people's perceptions of the marine environment and ecological engineering in harbours

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HIGHLIGHTS

- Most residents have a good understanding of harbour condition.
- Concern for the environment is, however, low in degraded harbours.
- Most residents support ecological engineering but have poor knowledge of initiatives.
- To improve harbour health, greater stakeholder engagement is needed.

GRAPHICAL ABSTRACT
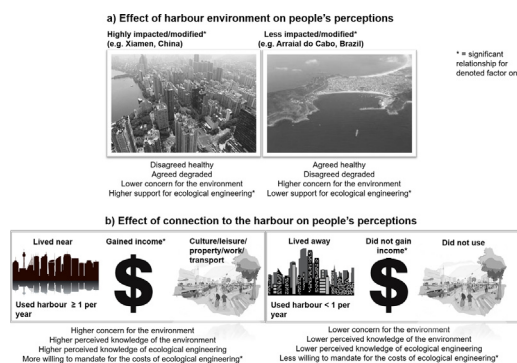
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ABSTRACT

Marine harbours are the focus of a diverse range of activities and subject to multiple anthropogenically induced pressures. Support for environmental management options aimed at improving degraded harbours depends on understanding the factors which influence people's perceptions of harbour environments. We used an online survey, across 12 harbours, to assess sources of variation people's perceptions of harbour health and ecological engineering. We tested the hypotheses: 1) people living near impacted harbours would consider their environment to be more unhealthy and degraded, be more concerned about the environment and supportive of and willing to pay for ecological engineering relative to those living by less impacted harbours, and 2) people with greater connectedness to the harbour would be more concerned about and have greater perceived knowledge of the environment, and be more supportive of, knowledgeable about and willing to pay for ecological engineering, than those with less connectedness. Across twelve locations, the levels of degradation and modification by artificial structures were lower and the concern and knowledge about the environment and ecological engineering were greater in the six Australasian and American than the six European and Asian harbours surveyed. We found that people's perception of harbours as healthy or degraded, but not their concern for the environment, reflected the degree to which harbours were impacted. There was a positive relationship between the percentage of shoreline modified and the extent of support for and people's willingness to pay indirect costs for ecological engineering. At the individual level, measures of connectedness to the harbour environment were good predictors of concern for and perceived knowledge about the environment but not support for and perceived knowledge about ecological engineering. To make informed decisions, it is important that people are empowered with sufficient knowledge of the environmental issues facing their harbour and ecological engineering options.

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1. Introduction

Harbours, coastal bodies of water that are sheltered by natural or artificial barriers (e.g. bays, ports and estuaries), have long served as the focal points of human settlement. Historically, harbours served as central hubs for trade and transport, with many locations also supporting commercial fishing industries (Pearson et al., 2016; Steinberg et al., 2016). More recently, human population growth and tourism around harbours has been fuelled by their high recreational and aesthetic value (Ghermandi and Nunes, 2013). By 2050, it is estimated that 50% of the world's populations will live in coastal cities, with many in harbour cities (Firth et al., 2016; McGranahan et al., 2007; Small and Nicholls, 2003).

The high value that society has placed on harbours for living, working and recreation has made them some of the most heavily modified environments on earth (Lotze et al., 2006). Anthropogenic threats to harbour environments include pollution, overexploitation of resources, habitat loss and degradation and species introductions (Airoldi and Beck, 2007; Crain et al., 2009). Additionally, in many harbours, artificial structures (e.g. seawalls, groynes, breakwaters, wharves) built to reclaim land, support shipping, fishing and recreational activities (Strain et al., 2018b) are now the dominant habitat type, replacing natural shorelines and marine ecosystems such as mangrove forests, seagrass beds, saltmarshes, and rocky and sedimentary shores (Heery et al., 2017; Lai et al., 2015; Prosser et al., 2017). These artificial habitats can have a myriad of negative impacts on native biodiversity and ecosystem functioning (Chapman and Underwood, 2011).

As awareness of the extent of harbour modification has grown, so too have scientific interest and investment in environmental management programs aimed at mitigating stressors, "greening" of artificial structures (hereafter termed ecological engineering) and rehabilitating lost or degraded ecosystems. Ecological engineering approaches include modifying the attributes of existing artificial structures (e.g. adding artificial rock pools, termed hard ecological engineering), replacing artificial structures with created or restored natural habitats (e.g. oyster reefs, termed soft ecological engineering), or combining created or restored natural habitats with artificial structures (e.g. mangroves with rocksills, termed hybrid ecological engineering) (Chapman and Underwood, 2011). While the most appropriate approach will depend on the environment as well as on engineering, ecological and socio-economic objectives, all projects have a common goal of building structures that benefit both humans and nature (Mitsch, 2012).

The success of such environmental management in achieving its goals is dependent on knowledge of how coastal marine ecosystems work, technical capacity and funding, legal permitting, politically willingness as well as on social acceptance (Cormier and Elliott, 2017; Elliott, 2013; Menz et al., 2013). Despite use of the best available environmental information, many conservation initiatives fail because affected stakeholders are not supportive of the desired actions (Ban et al., 2013; Jarvis et al., 2016). Understanding the attitudes, preferences, and behaviours of stakeholders, can assist in tailoring interventions to communities, and in ensuring compliance with recommendations (Ban et al., 2009). Support for ecological engineering often varies predictably among stakeholder groups, within harbours (Derkzen et al., 2017; Evans et al., 2017; Gray et al., 2017; Kienker et al., 2018; Liu et al., 2018; Morris et al., 2016; Smith et al., 2017; Strain et al., 2018a). Nevertheless, there are relatively few studies examining public perceptions of the overall health of harbour environments, and levels of environmental concern (Easman et al., 2018; Jarvis et al., 2015) and knowledge and willingness to contribute to the costs of ecological engineering initiatives, particularly in developing countries. Moreover, this information will assist ongoing efforts to implement ecological engineering initiatives aimed at protecting and restoring urban harbours.

Public perceptions of environmental health, their concern for the harbour environment and people's support of management interventions may be expected to vary spatially according to their usage of the environment (Kienker et al., 2018; Pacione, 2003), the distance they live from the waterway (Atkins et al., 2007), socio-economic status (Franzen and Meyer, 2009; Roca and Villares, 2008) and cultural factors (Madureira et al., 2015; Madureira et al., 2018; Priego et al., 2008). People's awareness of human impacts on their geographic location (Kienker et al., 2018) and proximity to degraded environmental locations (Gifford and Nilsson, 2014) may also influence people's perception of the harbour environment. At a local level, factors such as age, gender, income and education, and political ideology can be strong predictors of environmental concern in terrestrial environments (Fransson and Gärling, 1999; Liere and Dunlap, 1980). There is however, limited research on whether the factors that influence human perceptions of urban terrestrial environments (Ambrosius and Gilderbloom, 2015; Priego et al., 2008; Van den Berg et al., 2007) also apply to marine harbours. The development of an international and cross-cultural understanding of factors influencing human perceptions of harbour health and degradation, will help in developing strategies for building public

support of management interventions (Franzen and Meyer, 2009; Jarvis et al., 2016; Pacione, 2003).

At, at an individual level, perceptions of the harbour environment could be influenced by a person's connectedness to the harbour (Kienker et al., 2018). Studies have demonstrated that individuals who engage with nature frequently have a greater concern for the environment (Beery and Wolf-Watz, 2014; Gunderson, 2006; Nisbet et al., 2009; Raymond et al., 2010). Individuals connect to harbours in a variety of ways: work (e.g. commercial fishing, shipping, transportation, environmental management, science), transport (e.g. ferries), leisure (e.g. boating, swimming, recreational fishing, jogging/walking on the foreshore), culture (e.g. festivals, social gatherings or indigenous links) and by living nearby (Pearson et al., 2016). In terrestrial and coastal environments, a positive relationship exists between connection to place, including amount of time spent there by non-residents (Kelly and Hosking, 2008), and for residents, residency length (McCool and Martin, 1994). In some locations, the increasing connection and use of place can also cause increased damage to the surrounding environment (Kelly and Hosking, 2008). It is unclear however, whether these relationships extend to aquatic environments, where people typically live and work alongside the harbour environment rather than within it.

In this study, we assessed the sources of variation in perceptions towards harbour health and ecological engineering across twelve globally distributed locations using an online survey. We specifically focused on ecological engineering, among other management interventions, because it is an emergent approach, that is increasingly being utilised to 'green' grey infrastructure (Borsje et al., 2011; Chapman and Underwood, 2011; Mitsch, 2012). Specifically, we tested the hypotheses that: 1) people living by more impacted harbours would be more likely to consider their harbour environment unhealthy and degraded, be more concerned about the environment, be more supportive of ecological engineering and willing to contribute to the costs of ecological engineering projects than those living by less impacted harbours, and 2) people with greater connectedness to the harbour would be more concerned about and have greater perceived knowledge about the harbour environment, and be more supportive of, knowledgeable about

and willing to contribute to the costs of ecological engineering, than those with less or no connectedness.

2. Methods

2.1. Study sites

The survey was conducted in twelve harbours worldwide (Fig. 1). Harbours were selected based on their participation in the World Harbour Project (http://worldharbourproject.org) and had varying levels of harbour modification, environmental stressors, population density and socio-demographics (Aguirre et al., 2016; Airoldi et al., 2016; Chee et al., 2017; Knights et al., 2016).

2.2. Questionnaire

The survey assessed perceptions towards each harbour of people living, working or recreationally using foreshore areas within two kilometres of its waterways. It used both targeted (coastal managers and marine scientists) and convenience sampling (all other stakeholder groups) to capture the responses of multiple user groups (Kemper et al., 2003), broadly following the methodology reported in Kienker et al. (2018) and Strain et al. (2018a). This type of sampling was chosen as the best possible method for comparing multiple harbours across countries (Brown and Weber, 2012; Jarvis et al., 2015). It is an important sampling technique for raising public awareness of key issues and can contribute to more effective, durable and holistic decision and policy-making processes (Brown and Kyttä, 2014; Jarvis et al., 2015; Reed, 2008), however, it can be challenging to obtain a representative sample of the population (Blair et al., 2013).

To address these potential limitations, we sampled respondents at a variety of locations within each harbour, including street locations, shopping malls, private businesses and social events. The survey was also distributed online to people 18 years of age or over, and participants were recruited through advertisements on community boards, business cards, emails, social media, newsletters, mailing lists, or in
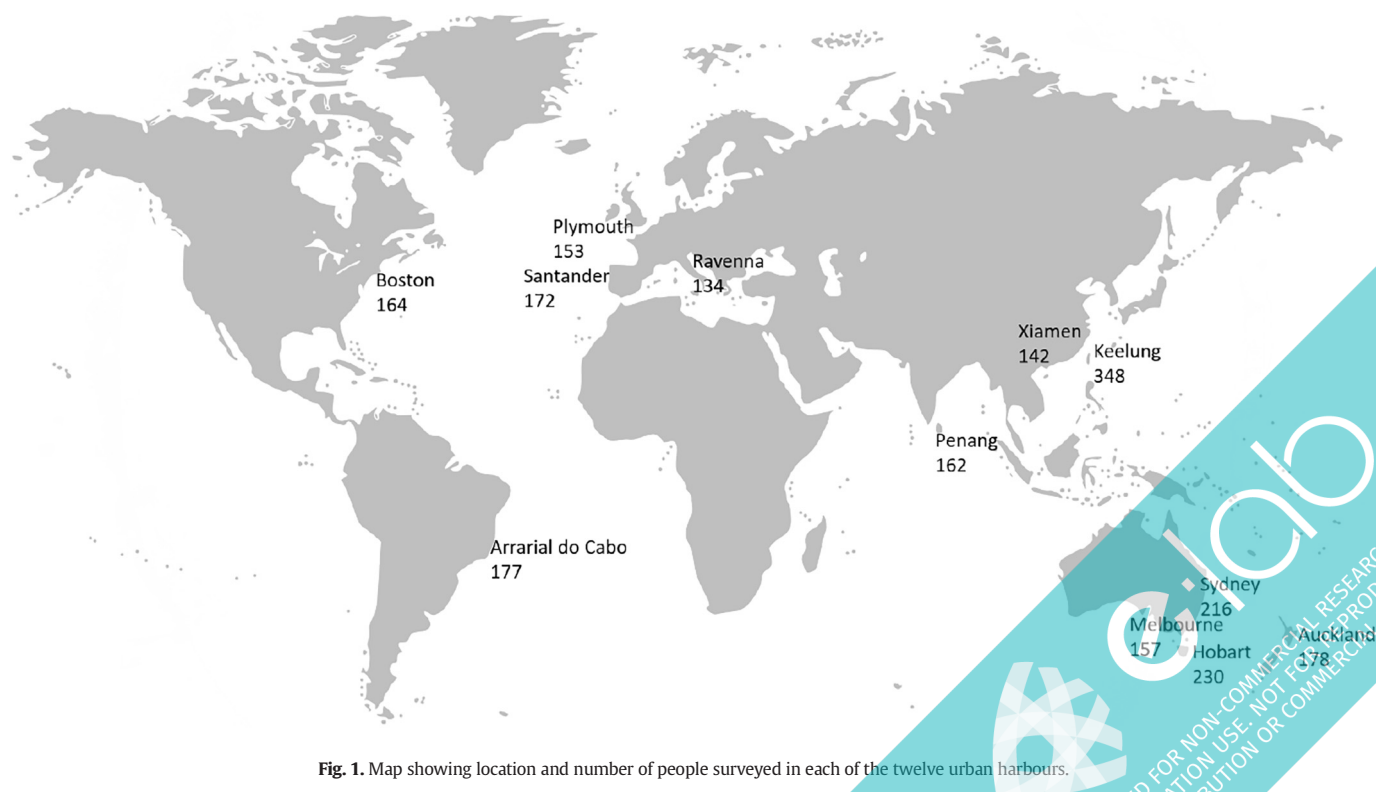

Fig. 1. Map showing location and number of people surveyed in each of the twelve urban harbours.

person (using a tablet or paper copy of the questionnaire) along the foreshore of each harbour. In addition, the responses of specific user groups (i.e. coastal managers and marine scientists) were solicited through direct emails, meetings, and social events. All respondents were provided with access to the participant information sheet (ethics approval reference number *H16175* University of NSW, Australia) before agreeing to undertake the survey (Fig. S1).

The survey was made available online through Surveymonkey (www.surveymonkey.com) or REDcap (Harris et al., 2009) between June and December 2017. The survey required approximately 10–15 min to complete and included 19 questions on three themes: harbour use, views on artificial structures and perceptions of ecological engineering. In this study, 15 questions were used in the analyses (Fig. S2). In all locations, the survey was presented to the respondents in their local language (i.e. English, Italian, Portuguese, Malay, Mandarin or Spanish), and for the subset of questions where pictures of man-made structures and ecological engineering initiatives were included, the examples were provided from the local harbour environment (Fig. S2). During the survey, we collected information about the percentage of their income the participants gained from the harbour and their individual income bracket per year (before tax). The individual income categories (very low, low, average, high and very high) for each location were determined from income brackets reported by the most recent government census data (either at city – Sydney, Melbourne, Auckland, Arraial do Cabo, Boston, Keelung, Santander or country level – Ravenna, Plymouth, Penang and Xiamen). The survey included questions with multiple choice, binary (yes or no) and 5-point Likert scale (2 answers in agreement with the statement, 1 neutral answer and 2 answers in disagreement with the statement) answers. This mix of multiple choice, binary and Likert scale answers allowed us to explore multiple perspectives. In all locations, participation in the survey was voluntary and without incentive.

2.3. Analyses

To assess the extent to which the survey sample was representative of the broader population at each location, we used binomial tests to assess any differences in sex ratios, age brackets and education levels, between our survey and the most recent government census of the population (see Table S4 for full details). For many locations, there was limited or no information available about the individual annual income brackets at the city level. Therefore, for all locations, we only tested for differences in the average annual income between the survey and census populations.

To assess the relationships between the status of the harbour environment and people's perceptions, two independent measures of impacts were calculated for each harbour (Table S3). The first was the cumulative impact index, which gives a relative measure of the intensity of human pressures in the harbour environment, for each country (average highest impact) through time, globally (Halpern et al., 2008). High scores (>12) are indicative of impacted systems, whereas low scores (<4.95) indicate less impacted systems (Halpern et al., 2008). The second metric of impact was the percentage of the harbour shoreline (main body of water only and excluding all tributaries) that was modified by artificial structures such as coastal defences, retaining walls, marinas and jetties, and other public amenities. The percentage of harbour shoreline modified by artificial structures was estimated and mapped from satellite images in Google Earth using images from 2016 to 2017 (Table S3). To ground truth this information, we also checked the figures estimated from Google Earth against existing values from the literature (Table S3). To explore the relationships between each of the two independent measures of impact and the perceptions towards harbour health and connectedness of individual people to harbours (see below details) across locations, we used principal components analysis (PCA). All variables were normalised to account for differences in measurement scales.

We used ordinal regression models to separately assess the relationship between the two measures of impact and the individual respondent's perceptions of harbour health (ordinal 5-point Likert-scale) and harbour degradation (ordinal 5-point Likert-scale), their concern for the harbour environment (ordinal 5-point Likert-scale) and their willingness to contribute to the costs of ecological engineering projects through donating money, paying government taxes or voting to ensure businesses included the costs in future developments (ordinal 5-point Likert-scale). Generalised linear models with a binomial distribution were used to assess whether people's support for ecological engineering (yes or no) varied as a function of the cumulative impact index or the percentage of harbour shoreline modified.

Four separate measures were used as indicators of people's connectedness to the harbour. These were: type of use (7 fixed levels = I don't use the harbour vs. culture, leisure, property, transport, paid work, unpaid work); frequency of use (8 fixed levels = I don't use the harbour, <1 visit per year, 4–6 months, 2–3 months, monthly, weekly, daily, I live here); percentage of income from the harbour (covariate, 7 levels = none, unknown, <10%, 11–20%, 21–50%, 51–80%, >81%) and number of years living on the harbour (covariate, 8 levels = I don't live here, <1 year, 1–2 years, 3–5 years, 6–10 years, 11–15 years, 16–20 years, >21 years). Using ordinal regression models, we assessed how each of these measures of connectedness varied among harbours (12 random levels) and explored if they were related to a respondent's (at the individual level) concern for the harbour environment (ordinal 5-point Likert scale), perceived knowledge of the harbour environment (ordinal 5-point Likert scale), perceived knowledge of ecological engineering (ordinal 5-point Likert scale) and willingness to contribute to the costs of ecological engineering projects through donating money, paying government taxes or voting to ensure businesses included the costs in future developments (ordinal 5-point Likert scale). To assess how support for ecological engineering (yes or no) varied as a function of these measures of connectedness and harbour (12 random levels), we used generalised linear models with a binomial distribution. For all analyses, we tested and found no effects of over dispersion using the AER library (Kleiber and Zeileis, 2008). The statistical significance (p < 0.05) of each fixed and random effect was determined by undertaking likelihood ratio tests on models with and without each effect. For all models, we calculated odd ratios and confidence intervals as a measure of the effect size for all significant dependent variables. All analyses were conducted in R version 3.4 (R Development Core Team, 2018).

3. Results

3.1. Participation rate and demographics

In total, 2392 people completed the survey, with 439 responses from coastal managers and marine scientists and 1953 responses from other stakeholders. Across the twelve locations there were 159 respondents who did not use or live by the harbour, and their responses were excluded from all analyses. The number of respondents per harbour ranged from 134 to 348 (Fig. 1). The responses per harbour is comparable to those used by other public perceptions studies on harbours (Evans et al., 2017; Kienker et al., 2018; Morris et al., 2016; Strain et al., 2018a). Across the locations, most (>73%) of the participants completed the survey in their native language and identified their understanding of the questions as either average or good (Table 1).

The sample demographics varied among the twelve harbours (Table 1). In most harbours, there were approximately equal numbers of males and females surveyed, with the most common age categories 18–34 or 35–54 years, the most common highest education levels either a college or technical and further education (TAFE) diploma or certificate, bachelor's or higher degree, and the most common individual annual income categories low to very low (Table 1). In Melbourne, Sydney, Plymouth and Santander however, there were more people who reported an individual income per year that was average rather

Table 1

Socio-economic characteristics of respondent's and their understanding of the survey questions in each location. Categories with the highest percentage of respondents are indicated in bold print and categories which are significantly different from the census population are indicated *p > 0.05 and – indicates census data is not available.

Region		Australasia				America		Europe			Asia		
Variables		Sydney	Melbourne	Hobart	Auckland	Arraial do Cabo	Boston	Plymouth	Ravenna	Santander	Keelung	Penang	Xiamen
Gender	Females (%)	**52.1**	**51.6**	**50.4**	47.8	48.3	**56.0**	41.2	46.4	42.1	**56.7**	**57.1**	44.3
	Males (%)	47.9	48.4	48.3	**52.2**	**51.7**	44.0	**58.9***	**50.6**	**58.0***	43.3	43.0	**55.7**
	Other (%)	0	0	1.3	0	0.56	0	0	0.6	0	0	0.6	0.6
Age	18–34 (%)	**39.2***	23.6	25.0	**47.3***	**50.3***	**61.2***	**47.5***	**49.7***	**44.3***	**63.3***	**64.3***	**89.9***
	35–54 (%)	38.7	**48.4***	**47.4***	30.0*	37.5*	16.6*	32.0	40.1*	44.3	34.1*	26.0	10.1
	55–73 (%)	21.7	24.2	25.4	21.7	11.7	21.7*	19.4	10.2*	10.8	2.4*	9.7	0*
	74–95 (%)	0.5*	3.8*	2.2	1.1	0.6	0.6*	1.2	0*	0.6	0.3*	0*	0*
Education	School	7.0*	4.5*	5.6*	13.9*	21.2*	26.9	8.6	22.2*	11.4*	0.5*	4.9*	2.38*
	College/TAFE diploma	14.8	14.0	19.4	12.8	8.3–	6.9	29.1–	NA	5.1–	9.7–	16.8–	2.38–
	Bachelor	38.7*	34.4*	32.3*	32.8	21.2*	29.2	29.7*	27.0*	26.7*	**52.4***	**60.0***	**57.74***
	Postgrad	39.7*	47.1*	42.7*	40.5*	49.1*	37.2*	32.6*	50.9*	67.0*	37.3*	18.3*	37.50*
Annual income	Very low (%)	18.0–	25.5–	32.9–	35.8–	26.8–	42.3–	21.7–	**31.8–**	16.5–	**54.4–**	**54.6–**	**61.3–**
	Low (%)	16.6–	12.8–	13.4–	20.1–	11.8–	12.0–	24.0–	21.0–	22.7–	8.7–	15.7–	11.3–
	Average (%)	22.6	16.5	16.9	15.1	16.2	11.5–	**25.2–**	7.2–	**34.7**	17.6–	21.1*	10.7*
	High (%)	**30.0–**	**31.2–**	26.0–	20.7–	23.5–	14.3–	20.0–	9.6–	13.7–	10.3–	7.1–	10.7–
	Very high (%)	12.9–	14.0–	10.8–	8.4–	21.8–	20.0–	9.1–	15.0–	12.5–	9.2–	1.6–	6.0–
People who answered the survey in their native language	(%)	90.8	96.2	100.0	86.1	99.5	92.0	100.0	98.2	96.6	80.3	73.0	74.4
Understanding of the survey	Majority	Good	Very good	Good	Good	Good	Good	Average	Good	Good	Average	Good	Average

than low or very low (Table 1). In most locations, the percentage of males and females surveyed (excluding Plymouth and Santander) reflected the sex ratio of census data (Tables 1 and S5). Additionally, of the eight harbours for which census income data were available, in six (Arrarial do Cabo, Santander and the four harbours of Australasia sampled), the percentage of people surveyed who earned the average individual income per year was comparable to census data (Tables 1 and S5). In contrast, in Penang, Keelung and Xiamen, the respondent's personal income per year (before tax) was significantly less in this study than the census data. In many locations, the percentage of survey respondents with bachelor or postgraduate degrees was greater than the general population, and in almost all locations, the age groups of 18–34 (with exceptions of Melbourne and Hobart) and 35–54 (with exceptions of Sydney, Plymouth and Xiamen), were overrepresented compared to the census data (Table 1 and S5).

3.2. Differences between locations in harbour environment and people's perceptions

There were key differences among locations in the levels of degradation, percentage of harbour shoreline modified and people's perception of the harbour environment and of ecological engineering, and their connectedness to the harbour environment (Table 2). The PCA analyses indicated that there were 5 axes with eigen values that were higher than 1 and accounted for 60.7% of the variance in the data. There was clear seperation in the levels of impact, people's perceptions of the harbour environment and ecological engineering and their connectness to the harbour between Asia/Europe and Australasia/America (Fig. S6).

The cumulative impact index and percentage of harbour shoreline modified were generally higher in the six European and Asian than the six Australasian and American harbours, surveyed (Table S3). The survey indicated people in Australasia and America generally had moderate to high concern for the environment, and average to good perceived knowledge of their harbour environment relative to people that were surveyed in Europe and Asia, who generally reported average concern for the environment and had average perceived knowledge of their harbour environment (Table 2). Across all locations, there was very high support for ecological engineering (>88%). Most respondents were in favour of paying government taxes (excluding Arrarial do Cabo, Ravenna, Plymouth, and Penang) to fund ecological engineering and

mandating businesses to include the costs of ecological engineering in future developments (all locations) but were unwilling to personally donate money towards the costs of ecological engineering (excluding Xiamen). Their perceived knowledge of ecological engineering was generally average to poor (Table 2).

In eight of the the twelve harbours, including six of the seven Australasia and Europe harbours survey (the exception being Plymouth as well as Boston and Keelung), the greatest reported use of the harbour was for lesiure activities (Table 2). In contrast, in Arrarial do Cabo paid work was the most common harbour activity, in Penang most people used the harbour for transport and in Xiamen most people used the harbour for lesiure and transport activities (Table 2). The respondents in Australaisa, Arrarial do Cabo, Plymouth and Santander generally lived alongside the harbour, while people in other locations while not living be the harbour but visited it throughout the year (Table 2). In all locations, the majority of respondents gained no income from the harbour (Table 2). In the four Australaisan harbours and Arrarial do Cabo, most of the respondents had lived by the harbour for over 21 years (Table 2).

3.3. Relationships between harbour environment and people's perceptions

Across the twelve harbours, people's perception of their harbour environment varied according to the status of the harbour environment, as measured by either the cumulative impact index or the percentage of harbour shoreline modified by artificial structures (Fig. 2, Tables 3 and S7). The people in countries with a higher cumulative impact index were more likely to disagree or strongly disagree that "the harbour environment is generally healthy" and agree or strongly agree that "the harbour environment has been degraded by human development" (Fig. 2, Tables 3 and S7), compared with those in countries with a lower cumulative impact index. Similarly, the respondents in locations with a greater percentage of harbour shoreline modified by artificial structures were more likely to disagree or strongly disagree that "the harbour environment is generally healthy" but less likely to agree or strongly agree that "the harbour environment has been degraded by human development" (Fig. 2, Tables 3 and S7), relative to people in less modified locations. Contrary to our predictions, the people in countries with a higher cumulative impact index or locations with a higher percentage of modified harbour shoreline were less concerned about the harbour environment than the respondents in countries with a

Table 2
Differences among locations in people's concern for the harbour environment (very poor, poor, average, good, very good), perceived knowledge about the harbour environment (none, low, average, moderate, high), perceived knowledge of ecological engineering (answered yes) and perceived knowledge of ecological engineering (very poor, poor, average, good, very good), willingness to donate money for ecological engineering projects, pay taxes for ecological engineering projects and mandate for including ecological engineering in future projects (strongly disagree, disagree, neutral, agree, strongly agree), type of harbour use (I don't use the harbour, culture, leisure, property, paid or unpaid work), frequency of harbour use (I don't use the harbour, <1 visit per year, 4–6 months, 2–3 months, monthly, weekly, daily, I live here), income from the harbour (none, unknown, <10%, 11–20%, 21–50%, 51–80%, >81%), number of years living by the harbour (I don't live here or 0 years, <1 year, 1–2 years, 3–5 years, 6–10 years, 11–15 years, 16–20 years, >21 years). The category with the highest proportion of responses is reported for each location.

| Region	Australasia				America		Europe			Asia		
	Sydney	Melbourne	Hobart	Auckland	Arraial do Cabo	Boston	Plymouth	Ravenna	Santander	Keelung	Penang	Xiamen
Concern for the environment	High (0.45)	High (0.68)	High (0.43)	High (0.47)	High (0.65)	High (0.44)	Average (0.32)	Moderate–average (0.34)	Average (0.52)	Average (0.47)	Moderate (0.45)	Average (0.47)
Perceived knowledge about the environment	Average (0.42)	Good (0.44)	Average (0.32)	Average–good (0.32)	Good (0.33)	Average–good (0.26)	Average (0.33)	Average (0.34)	Average (0.47)	Average (0.52)	Average (0.54)	Average (0.44)
Support for ecological engineering	Yes (0.95)	Yes (0.95)	Yes (0.91)	Yes (0.94)	Yes (0.97)	Yes (0.98)	Yes (0.88)	Yes (0.95)	Yes (0.90)	Yes (0.99)	Yes (0.95)	Yes (0.98)
Perceived knowledge of ecological engineering	Poor (0.35)	Poor (0.32)	Poor (0.33)	Poor (0.39)	Very poor (0.37)	Average (0.40)	Poor (0.35)	Poor (0.38)	Average (0.33)	Average (0.46)	Average (0.48)	Poor (0.37)
Donate money for ecological engineering projects	Disagree (0.32)	Neutral (0.33)	Disagree–Neutral (0.33)	Disagree–neutral (0.35)	Disagree–neutral (0.28)	Neutral–agree (0.38)	Neutral (0.39)	Disagree–neutral (0.34)	Neutral (0.35)	Neutral (0.45)	Neutral–agree (0.38)	Agree (0.37)
Pay taxes for ecological engineering projects	Agree (0.47)	Agree (0.42)	Agree (0.40)	Agree (0.42)	Disagree (0.40)	Agree (0.52)	Neutral (0.38)	Agree–disagree (0.31)	Agree (0.38)	Strongly agree (0.35)	Neutral–disagree (0.35)	Agree (0.46)
Mandate inclusion in future developments	Agree (0.47)	Agree (0.43)	Agree (0.45)	Agree (0.49)	Strongly agree (0.43)	Strongly agree (0.42)	Agree (0.44)	Agree (0.49)	Agree (0.52)	Strongly agree (0.73)	Agree (0.45)	Agree (0.63)
Type of harbour use	Leisure (0.44)	Leisure (0.44)	Leisure (0.44)	Leisure (0.50)	Paid work (0.45)	Leisure (0.44)	Property (0.34)	Leisure (0.47)	Leisure (0.55)	Leisure (0.53)	Transport (0.37)	Leisure–transport (0.28)
Frequency of harbour use	Living (0.31)	Living (0.45)	Living (0.50)	Living (0.26)	Living (0.43)	2–3 months (0.30)	Living (0.37)	2–3 months (0.25)	Living (0.40)	<1 per year (0.46)	4–6 months (0.17)	<1 per year (0.22)
Income from the harbour	None (0.42)	None (0.65)	None (0.45)	None (0.53)	None (0.46)	None (0.66)	None (0.50)	None (0.84)	None (0.57)	None (0.84)	None (0.74)	None (0.81)
Number of years living by the harbour	0–>21 years (0.21)	>21 years (0.39)	>21 years (0.29)	0–>21 years (0.23)	>21 years (0.26)	0 years (0.37)	0 years (0.32)	0 years (0.50)	>21 years (0.44)	0 years (0.66)	0 years (0.61)	0 years (0.51)
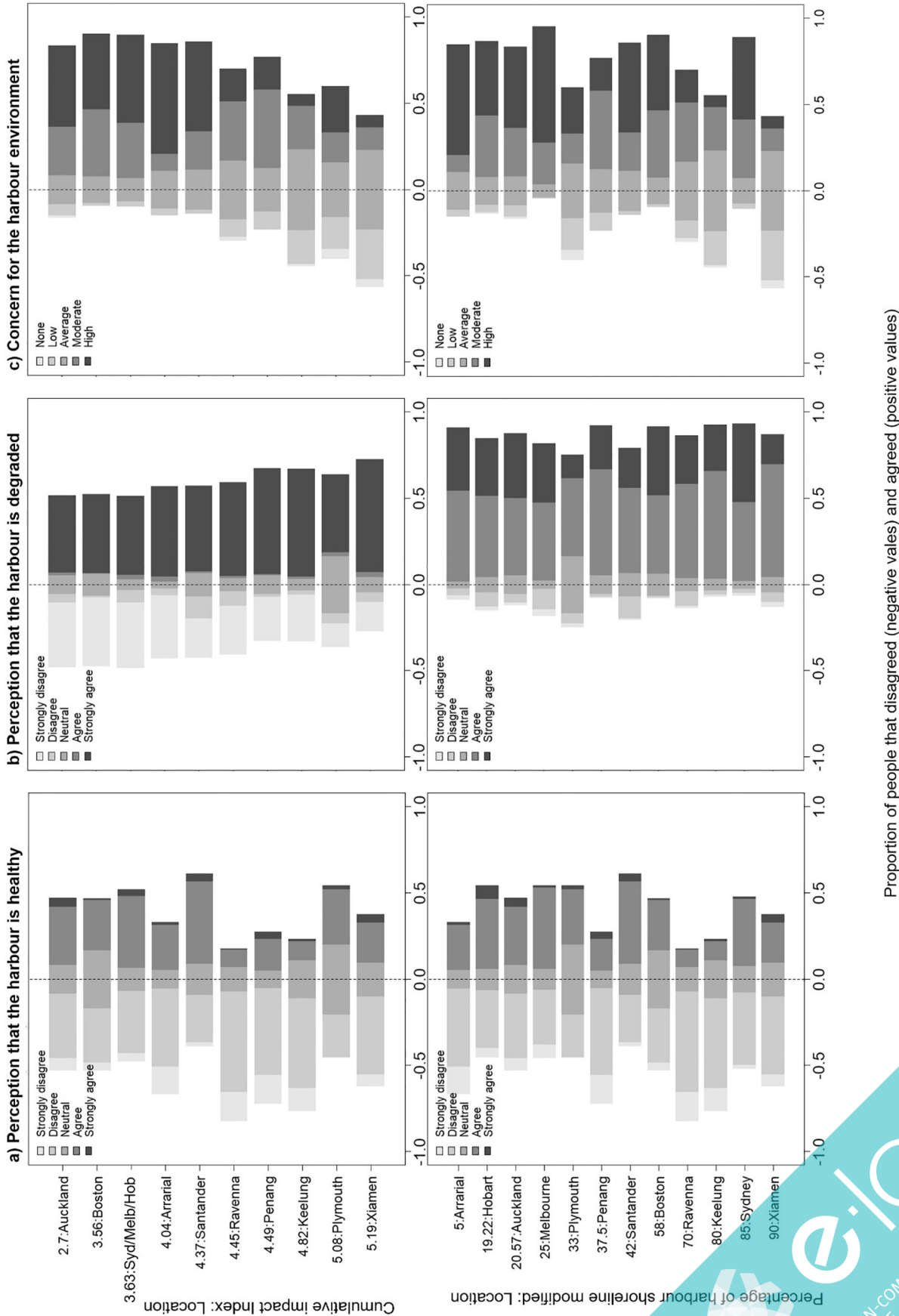
Fig. 2. The relationship between harbour environmental condition (cumulative impact index and the percentage of harbour waterway modified by artificial structures) and respondents perceptions (proportion of people that agreed and disagreed) of a) harbour health b) harbour degradation by human development and their c) concern for the harbour environment. The dotted vertical line shows the netural position. Syd = Sydney; Melb = Melbourne; Hob = Hobart.
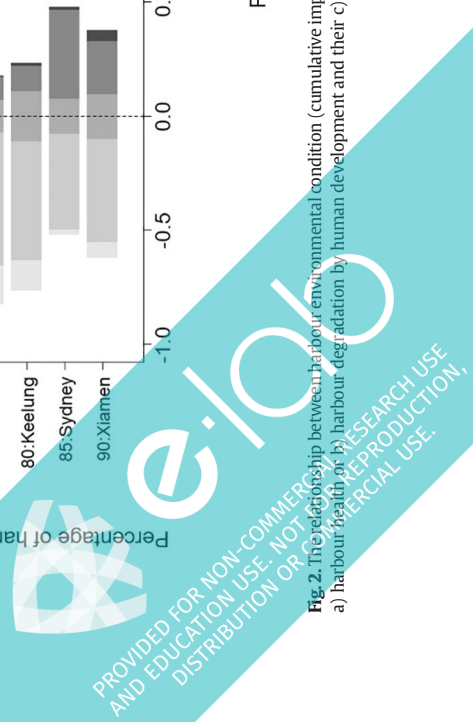
Table 3
Effect size (odds ratio and confidence intervals (0.25–97.5%)) of the relationships between the status of the harbour environment (as measured by either the cumulative impact index or the percentage of harbour shoreline modified by artificial structures) and people's perceptions of harbour health, degradation, and concern for harbour environment, support for ecological engineering and willingness to contribute to the costs of ecological engineering (see Table S5 for full details). Significant relationships are indicated in bold print.

	Perception of harbour health	Perception of harbour degradation	Concern for the harbour environment	Support for ecological engineering	Donate money for ecological engineering	Pay taxes for ecological engineering	Vote to ensure business include costs of ecological engineering in future developments
Cumulative impact index	**0.64** **(0.56–0.74)**	**1.46** **(1.31–1.64)**	**0.32** **(0.28–0.36)**	1.21 (0.92–1.58)	1.25 (1.00–1.38)	1.11 (1.00–1.22)	1.15 (1.00–1.28)
Percentage of harbour shoreline modified by artificial structures	**0.98** **(0.96–0.99)**	0.98 (0.97–0.99)	**1.02** **(1.02–1.03)**	**1.02** **(1.01–1.02)**	1.01 (1.00–1.01)	**1.02** **(1.02–1.02)**	**1.01 (1.01–1.01)**

lower cumulative impact index or harbours with less modified shoreline (Fig. 2, Tables 3 and S7). The proportion of respondents that were supportive of ecological engineering and agreed or strongly agreed to pay government taxes for ecological engineering projects and vote to ensure businesses included costs of ecological engineering in future developments increased with the percentage of harbour shoreline modified but was unrelated to the cumulative impact index (Tables 3 and S7). There were no clear relationships between a harbour's environmental status and people's willingness to donate money towards ecological engineering projects (Tables 3 and S7).

3.4. Relationships between connection to the harbour and location and individual perceptions

Respondents' perceptions of the harbour environment and of ecological engineering varied within harbours, the latter according to the type and frequency of their harbour use (Figs. 3–4; Tables 4 and S8). Overall, the people who used the harbour for cultural activities, leisure, paid and unpaid work and transport or lived on it (i.e. owned or rented property) had a significantly higher concern for the harbour environment and a greater perceived knowledge of the harbour environment relative to those who did not use the harbour for any activities or did not live alongside it (Fig. 3, Tables 4 and S8). Similarly, people who used the harbour for any activity, visited the harbour more than once per year, gained >11% of their income from the harbour or lived near harbours for longer than 1 year had significantly greater concern for the harbour environment and a higher perceived knowledge of the harbour environment than people who did not use the harbour, used the harbour less frequently, derived 10% or less of their income from the harbour or lived near the harbour for less time (Fig. 3, Tables 4 and S8). People who used the harbour for any activity or gained >11% of their income from the harbour were also more likely to vote to ensure businesses included the costs of ecological engineering in future developments (Tables 4 and S8). There were also significant but weak (small effect sizes) relationships between all measures of connectness (type of use, frequency of use, % of income gained and number of years living near the harbour) and people's perceived knowledge of ecological engineering (Tables 4 and S8). Willingess to personally donate to ecological engineering projects or to pay government taxes towards ecological engineering projects displayed no relationship with connectedness to harbour (Table S8). In contrast, there was no clear relationship between type of harbour use, frequency of harbour use, the number of years living by a harbour, or percentage of income on support for ecological engineering (Tables 4 and S8).

4. Discussion

There is an increasing interest in understanding the factors that influence people's perceptions of urban environments to improve their social acceptance for conservation and management activities (Ambrosius and Gilderbloom, 2015; Berenguer et al., 2005; Janse and Konijnendijk, 2007; Priego et al., 2008; Van den Berg et al., 2007). This study, for the first time, assessed whether the factors that influence human perceptions of modified terrestrial ecosystems (Ambrosius and Gilderbloom, 2015; Priego et al., 2008; Van den Berg et al., 2007) apply to marine harbours. As predicted, we found that people's perception of world harbours as healthy or degraded reflected the degree to which they were impacted, but there was a negative relationship between the degree of impact and their concern for the harbour environment. Despite this, there was a positive relationship between the percentage of harbour waterway modified and the extent of support for ecological engineering and people's willingness to pay government taxes or vote to ensure businesses include ecological engineering initiatives in future developments (Kienker et al., 2018). At the individual level, all measures of connectedness to the environment were good predictors of concern for and knowledge about the harbour environment, and knowledge of ecological engineering but not support for or willingness to pay for ecological engineering.

Urban community perceptions of their environment can be influenced by differing cultural values and socio-economic characteristics (Madureira et al., 2015; Madureira et al., 2018; Priego et al., 2008). We found differences among locations in people's perception of the harbour environment and of ecological engineering. While people surveyed at the six Australasian and American harbours generally had high concern and average to good knowledge of the harbour environment (Kienker et al., 2018; Morris et al., 2016), people surveyed at the six European and Asian harbours reported only average concern for the environment and average knowledge of the environment. These differences could be attributed to the faster rates of harbour development, increasing population densities or habituation (decreasing concern after repeated exposure to impacted and degraded harbour environments) in the harbours that were surveyed in Europe and Asia as opposed to the harbours that were surveyed in Australasia and America (Madureira et al., 2015; Madureira et al., 2018; Pacione, 2003). Alternatively, these results could be linked to greater media attention and scientific interest in ecological engineering in Australia and America relative to other locations (Morris et al., 2018; Strain et al., 2018b). Active and publicly visible ecological engineering projects may make the public more aware of the plight of harbour environments and concerned for them. Greater understanding of the factors leading to these cultural differences in the perception of people towards the harbour environment will be critical in developing locally relevant management solutions.

Understanding how people's perceptions of ecological health and degradation correlate with reality is essential for developing robust and effective policy and management strategies (Jefferson et al., 2015; Scyphers et al., 2015). Where populations do not perceive the full severity of ecological damage, appropriate management strategies may not be developed or implemented, and ecosystems are at risk of further degradation (Burger, 2003; Druschke and Hychka, 2015; McManus, 2006). A disconnect between perception and reality may occur due to the shifting baseline phenomenon (McHarg and Mumford, 1969; Pauly, 1995) whereby changes in the state of the environment occur
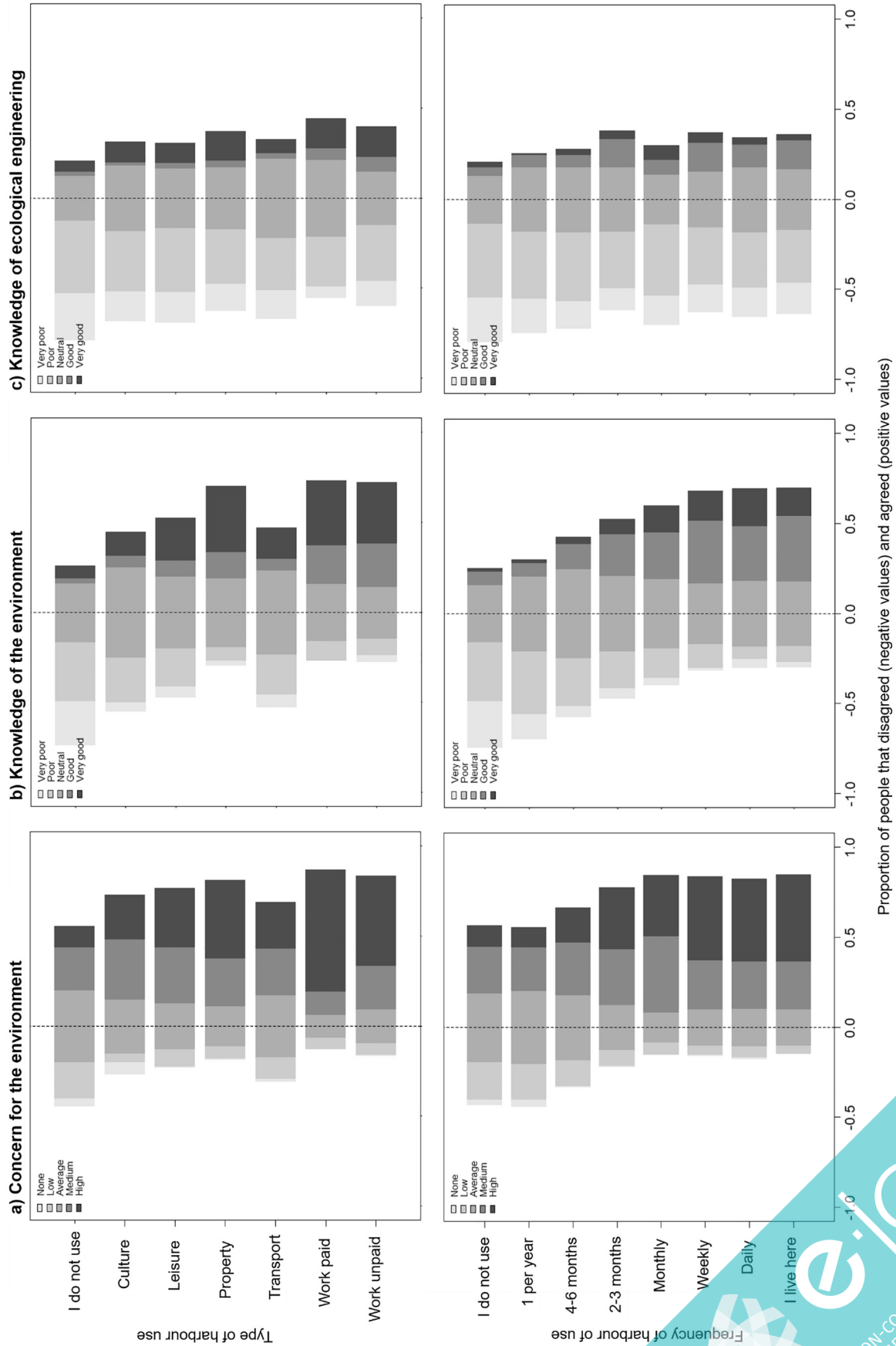
Fig. 3. Relationships between respondent's type and frequency of harbour use and their (proportion of people that agreed and disagreed) a) concern for the harbour environment, b) perceived knowledge about the harbour environment and (c) perceived knowledge of ecological engineering. The dotted vertical line shows the neutral position.
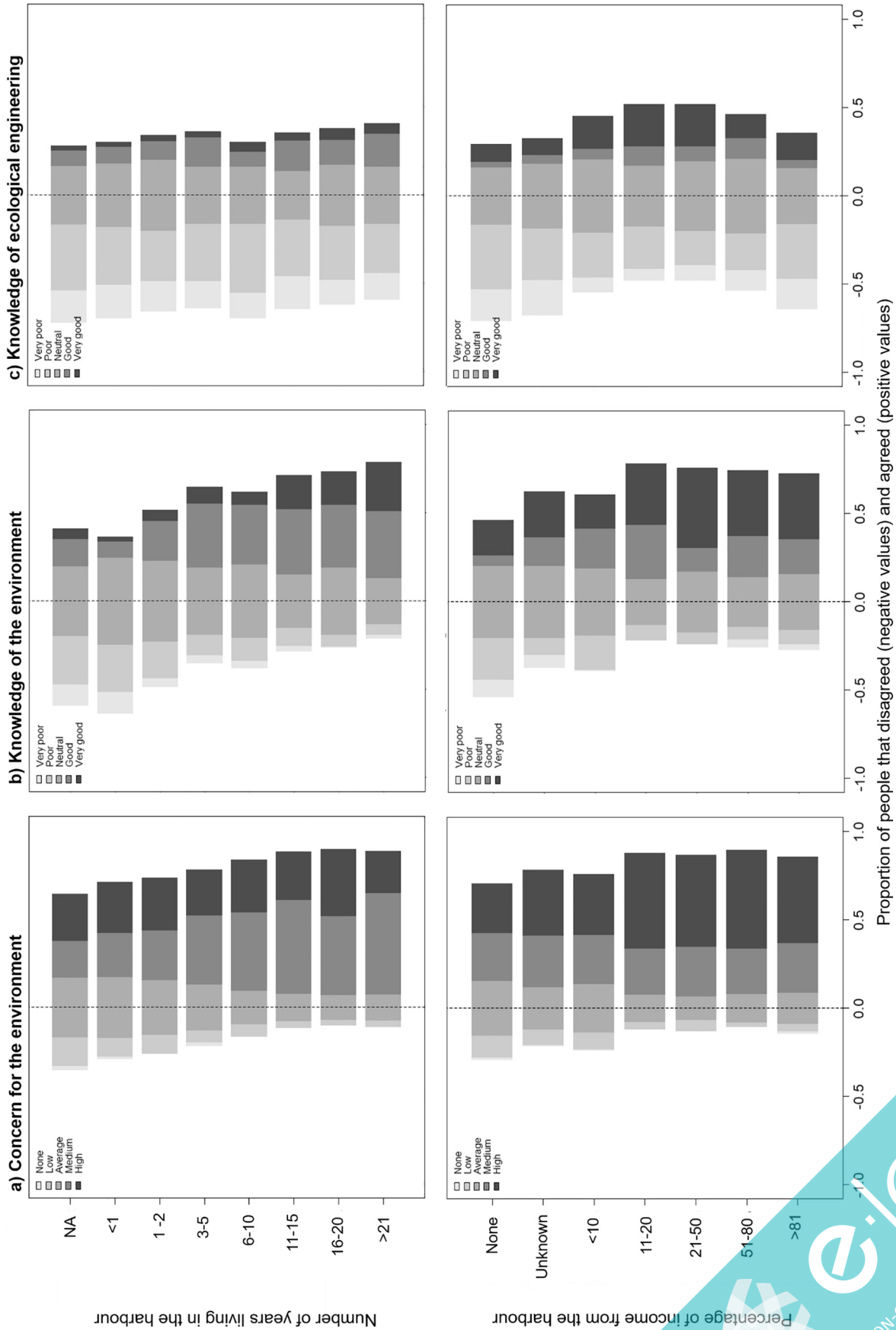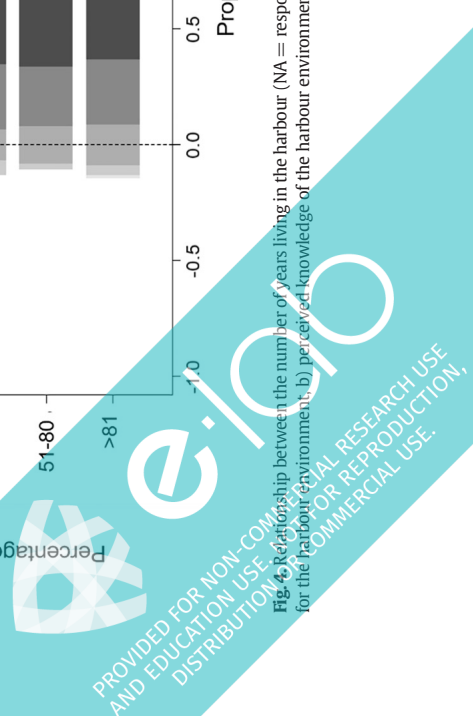
Table 4
Effect size (odds ratio and confidence interval (0.25–97.5%)) relationships between people's connection to the harbour (as measured by type and use of the harbour, income from the harbour and years living in the harbour) and support for ecological engineering (see Table S6 for full details). Significant relationships are indicated in bold print.

	Concern for the environment	Perceived knowledge of the harbour environment	Support for ecological engineering	Perceived knowledge of ecological engineering	Donate money for ecological engineering	Pay taxes for ecological engineering	Vote to ensure business include costs of ecological engineering in future developments
Type of use	**1.29 (1.23–1.35)**	**1.44 (1.37–1.52)**	1.10 (0.97–1.25)	**1.82 (1.13–1.24)**	0.95 (0.90–1.00)	1.03 (0.97–1.09)	**1.13 (1.08–1.87)**
Frequency of use	**1.41 (1.36–1.46)**	**1.41 (1.36–1.46)**	1.01 (0.93–1.08)	**1.08 (1.05–1.11)**	0.92 (0.89–1.00)	0.94 (0.91–1.00)	1.02 (0.99–1.05)
Income from the harbour	**1.18 (1.15–1.22)**	**1.25 (1.22–1.29)**	1.02 (0.94–1.10)	**1.06 (1.03–1.09)**	0.94 (0.92–1.00)	0.94 (0.92–1.00)	**1.04 (1.03–1.08)**
Number of years living in the harbour	**1.28 (1.24–1.32)**	**1.36 (1.31–1.41)**	1.01 (0.94–1.09)	**1.07 (1.05–1.11)**	0.93 (0.91–1.00)	0.96 (0.93–1.00)	0.97 (0.94–1.00)

over time, but populations fail to record or remember by how much, resulting in changing perceptions by each generation of what is "natural".

Our twelve locations had very different histories of development (Steinberg et al., 2016). For example, the Port of Ravenna was developed by Roman Emperor Augustus (31 BCE) (Airoldi et al., 2016), and the anthropogenic activities around Xiamen began in 282 CE (Zhang et al., in review). In contrast, European settlement of the Derwent Estuary in Hobart and Waitematā Harbour in Auckland (Aguirre et al., 2016) dated only to the late 1700s and early1800s, and extensive development of these locations commenced in the 1800s. Despite the differing histories of development in the twelve harbours, we found that the people perceptions of harbour health and degradation correlated strongly with actual harbour status, using each of two independent measures of degradation – the cumulative impact index and the percent of harbour waterway that is modified. In contrast, we found greater concern for harbour environments among the relatively less developed and degraded harbours (e.g. Hobart and Auckland), than the more developed and degraded harbours (e.g. Ravenna and Xiamen). This finding could be a result of the shifting baseline syndrome (sensu Pauly, 1995), where people living in degraded systems have lower expectations or perceptions of a healthy ecosystem. Interestingly, despite the relatively coarse level of information about impacts provided by the cumulative impact index (country level, with 10 harbours classified as less impacted), largely concordant results were produced independent of whether percentage of harbour waterway modification or cumulative impact index was used as the metric of degradation.

Assessing the relationship between people and place is important for predicting how various stakeholders will rate their concern for the harbour environment and support for conservation (Jefferson et al., 2015; Wyles et al., 2014). In this study, we found various measures of connectedness (frequency of use, type of activities, percentage of income and number of years living near the harbour) were positively correlated with the people's concern and perceived knowledge about the harbour environment. These results are not surprising given that long-term residents tend to have a stronger connection with place as local knowledge increases, and social networks and community ties strengthen over time (Hay, 1998; Kelly and Hosking, 2008). Contact with nature has also been found to be beneficial to both people's physical and mental health (Capaldi et al., 2014; Nisbet and Zelenski, 2011) and can result in pro-environmental behaviour (Beery and Wolf-Watz, 2014; Nisbet et al., 2009).

As in other studies, there was a very high support (>88%) and willingness to pay indirectly (i.e. government taxes and mandate) for the costs of ecological engineering, across most locations (Evans et al., 2017; Kienker et al., 2018; Morris et al., 2016). In contrast, there were only weak relationships between connectedness to the harbour environment and the people's knowledge of ecological engineering and willingness to vote to ensure business included the costs of ecological engineering in future developments. This may be because ecological engineering in the coastal realm is a relatively new discipline (Borsje et al.,

2011; Chapman and Underwood, 2011; Mitsch, 2012) and there are many forms of ecological engineering which are not visible (e.g. subtidally constructed mussel or oyster reefs) or accessible to the public (e.g. ecological habitat enhancements of seawalls). These results highlight the need to provide accessible examples of ecological engineering projects (e.g. Barangaroo https://www.barangaroo.com/) to increase awareness and knowledge about the benefits of these management strategies for the harbour environment (Kabisch et al., 2016).

In this study, we combined two types of non-probabilistic sampling – purposive and convenience, to provide crucial insights into what people think about their harbour environment, and ecological engineering. This type of sampling was used to provide large scale and cost-effective observations, that can be difficult to achieve with other methods (Brown and Weber, 2012; Jarvis et al., 2015). We compared the data collected via the survey to equivalent census information at city or country level. Across the twelve locations, we found the proportion of males and females (excluding Plymouth and Santander) and their average individual income per year (excluding Penang, Keelung and Xiamen) did not differ from census information but the percentage of highly educated people with a university degree, and the age groups of 18–34 and 35–54 were overrepresented relative to the census data. These biases may be due to several reasons, such as the online administration of the survey, the survey's non-inclusion of people under 18 years and a greater interest in the subject by more educated people. Alternatively, there could be fundamental differences in the socio-economic characteristics of harbour users relative to city or country populations. Further study with greater social diversity and using a range of methods is required to distinguish between these possibilities. Irrespective, our results provide important insights into some of key harbour and individual level factors which influence the people's perceptions of harbour environments and ecological engineering.

4.1. Recommendations

Overall, we revealed that most urban people generally have a good understanding of the condition of the harbour environment and are supportive of the multiple potential benefits offered by local ecological engineering initiatives for marine artificial structures (Evans et al., 2017; Kienker et al., 2018; Morris et al., 2016). However, the main challenge identified by the survey is a need to empower the public with the knowledge necessary to make more informed decisions about management and policy options for urban harbours (Gelcich et al., 2014), as a high proportion of people within each harbour rated their knowledge of ecological engineering as poor or very poor. This was particularly important in the harbours we surveyed in Europe and Asia, which had high levels of degradation, a high percentage of modification by artificial structures, but only average concern about the harbour environment.

Low levels of knowledge regarding local ecological engineering interventions may be addressed through greater stakeholder consultation in development and management plans, open meetings (e.g. http://www.rebuildbydesign.org/our-work/all-proposals/winning-projects/

ny-living-breakwaters) and highly visible and accessible projects that showcase environmental management strategies to the public (Kabisch et al., 2016). These projects may also achieve greater public acceptance by more firmly embedding environmental education in school and university curricula (Palmer, 2002), providing financial incentives for uptake (Scyphers et al., 2015; Sutton-Grier et al., 2018), and developing standardised monitoring tools to engage with citizen scientists (Toft et al., 2017).

Additionally, because connection (either living alongside or regular user) to harbours was a key predictor of an individual's concern for, and perceived knowledge about, the harbour environment, programs that foster people to be active in their harbour area, may effective at increasing environmental awareness (Schultz, 2011). The increasing interest in large-scale urban renewal projects that remove physical barriers between people and waterways by reinstating foreshore environments could also help to rebuild their connectedness to harbour environments (Chan and Lee, 2008; Liu et al., 2018). Community engagement initiatives such as foreshore cleaning events or volunteer service days could also help to rebuild these connections. It is imperative that waterfront projects integrate ecological and socio-economic perspectives into the planning process to achieve true success across multiple stakeholder groups (Sairinen and Kumpulainen, 2006; Yepsen et al., 2016).

Conflict of interest

The authors have no actual or potential conflict of interest including any financial, personal or other relationships with other people or that could inappropriately influence, or be perceived to influence, their work.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.12.285.

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