Mitigating the Impacts of Offshore Windfarms on the Taiwanese White Dolphin *(Sousa chinensis taiwanensis)*

An expert workshop held in Taipei (Taiwan), 17-20 April 2017

Held under the auspices of the Eastern Taiwan Strait *Sousa* Technical Advisory Working Group (ETSSTAWG)

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Executive Summary

Large-scale offshore windfarms are planned for the eastern Taiwan Strait, an area adjacent to, or in, the priority habitat for the Critically Endangered Taiwanese white dolphin (*Sousa chinensis taiwanensis*). Noise disturbance has been described as one of the five major threats to the recovery of this isolated population, which has a restricted range along the west coast of Taiwan. Since sound transmits readily over large distances underwater, the construction and operation of 600 to 1,000 wind turbines may have severe impacts on the remaining dolphins (which number fewer than 75) and may lead to their extinction. The Eastern Taiwan Strait *Sousa* Technical Advisory Working Group (ETSSTAWG) was asked by the Taiwanese conservation group, *Wild at Heart*, to convene an applied international workshop to characterise the nature and extent of this additional threat and to describe potential solution-oriented practices that would mitigate this threat.

Experts from around the world met in Taipei, Taiwan, on 17-20 April 2017. The group shared the latest findings from their disciplines, including from the relevant scientific literature; reviewed and discussed the threats posed by the proposed windfarm projects to the very small population of Taiwanese white dolphins in their restricted range; and devised a toolbox for local 'best practices' for industry and government managers to apply to project plans, reviews, and operations. Central among the principles developed for consideration were:

1) Locate the greatest threats resulting from the turbines away from areas where dolphins are found;
2) Design engineering practices that are specific to the Taiwanese white dolphin, its habitat, and its specific vulnerabilities, to reduce noise disturbance during construction, operation and decommissioning;
3) Work with commercial fishers to reduce the threat of fisheries interactions now and during windfarm construction and operation, since these activities may exacerbate the current impacts of fisheries.

The group concluded that it will be necessary to directly assess and monitor the impacts from windfarm construction and operation on the Taiwanese white dolphin, in the context of its specific vulnerabilities as a small population with a restricted range. Taiwan should develop its own set of best practices for windfarm development because following textbook examples for abundant, widely-ranging species (such as the harbour porpoise, *Phocoena phocoena*, in the North Sea) will not be effective

The group converged on a win-win solution to mitigate the impacts of fisheries, the most pressing threat facing the Taiwanese white dolphin. Should windfarm proponents embark on a partnership with fishers so as to protect dolphins wherever they be encountered, there exists the potential for this sector to contribute to the long term recovery of the Taiwanese white dolphin population. If construction and operation of offshore windfarms are done properly, in ways that effectively mitigate their impacts, as well as the impacts of existing threats, these developments offer

the promise of clean energy and increased domestic energy security in Taiwan, as well as hope for the Taiwanese white dolphin.

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1. Introduction

Wind power as a renewable, clean energy source is undergoing rapid development throughout the world, including in many nations in Asia. To reduce and avoid increasing conflicts with other uses of land space, building wind turbines (a cluster of which is known as a windfarm) offshore has also become increasingly attractive. However, this increases the likelihood for such projects to have an impact on marine species such as cetaceans in coastal waters.

Mitigation measures currently proposed by windfarm proponents in the eastern Taiwan Strait may be adequate for those cetacean species that are more abundant and wide-ranging in these waters, but given the general lack of information on these populations, windfarm risks cannot be dismissed without further study. In addition, small populations of cetaceans with restricted ranges are at particular risk from windfarm developments. The eastern Taiwan Strait is the only home of the Critically Endangered[1] Taiwanese white dolphin[2], *Sousa chinensis taiwanensis*, and this subspecies will require specialized mitigation as plans for windfarms proceed.

2. Taiwanese White Dolphins and Windfarms

2.1. The Proposed Windfarms

In the shallow coastal waters off western Taiwan, large offshore windfarm developments have been proposed, with a long-term target to supply at least 3,000 MW by the year 2025. This figure is likely to require the installation of at least 600 turbines. As of April 2017, two demonstration turbines and two meteorological masts have been installed offshore of Miaoli and Changhua counties (Fig 1).

These proposed windfarm developments border or overlap the habitat, including its highest density areas (Dares et al. 2017; Fig 1 and Fig 2), of the only endemic subspecies of cetacean in Taiwan, the Taiwanese white dolphin (Wang et al. 2015). No empirical data on the impacts, if any, of the two demonstration turbines on the dolphins were available at the time of the workshop.

[1] http://www.iucnredlist.org/
[2] http://www.iucnredlist.org/details/133710/0

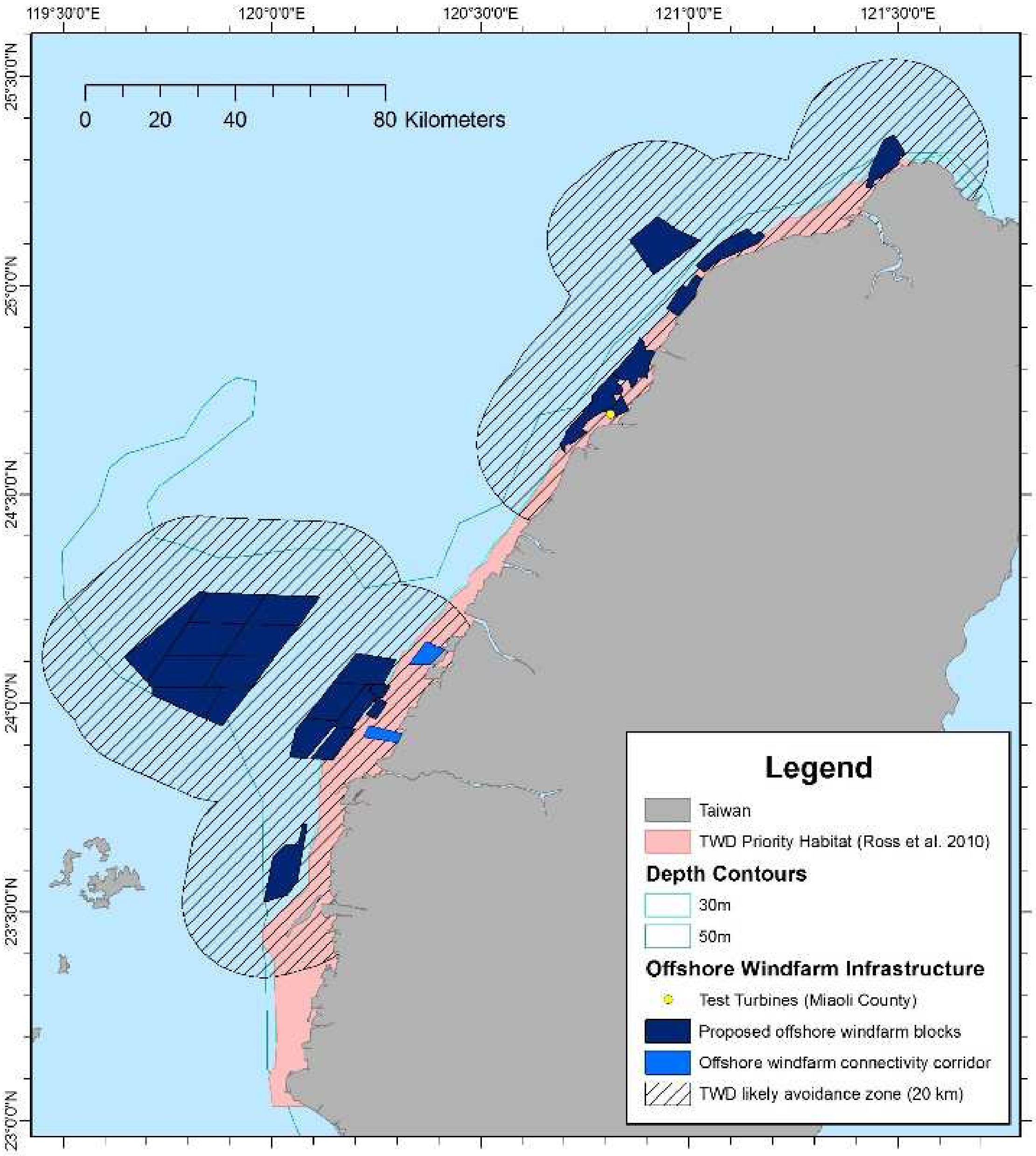

Figure 1. The location of proposed wind farm blocks and designated priority habitat of the Taiwanese white dolphin (see figure 2) and the 20km zone within which noise from construction of the wind turbines (if unmitigated) can affect dolphins and other cetaceans. Wind farm blocks that overlap with and are closest to the priority habitat of the Taiwanese white dolphin are of particular concern as standard noise mitigation techniques may not be sufficient to prevent negative impacts from construction methods such as percussive pile driving.

2.2. Current Population Status

This subspecies of Indo-Pacific humpback dolphin has been assessed by the IUCN Red List of Threatened Species as *Critically Endangered* (Wang et al. 2017a), due to its low abundance of 74 individuals (CV=4%; Wang et al. 2012), an inferred decline in abundance (Araújo et al. 2014; Huang et al. 2014), its highly-restricted, year-round distribution (Ross et al. 2010; Wang et al. 2007; Wang and Yang 2011) (Fig 2), and a number of major threats to the population (Wang et al. 2007a,b, Reeves et al. 2012, Ross et al. 2010, Dungan et al. 2011, Wang et al. 2017b). The restricted distribution of Taiwanese white dolphins consists of nearshore waters less than 3 km from shore and shallower than 30 m and usually in or near sources of freshwater (Dares et al. 2014; Ross et al. 2010; Wang et al., 2004a, 2007a, 2007b) (Fig 2).

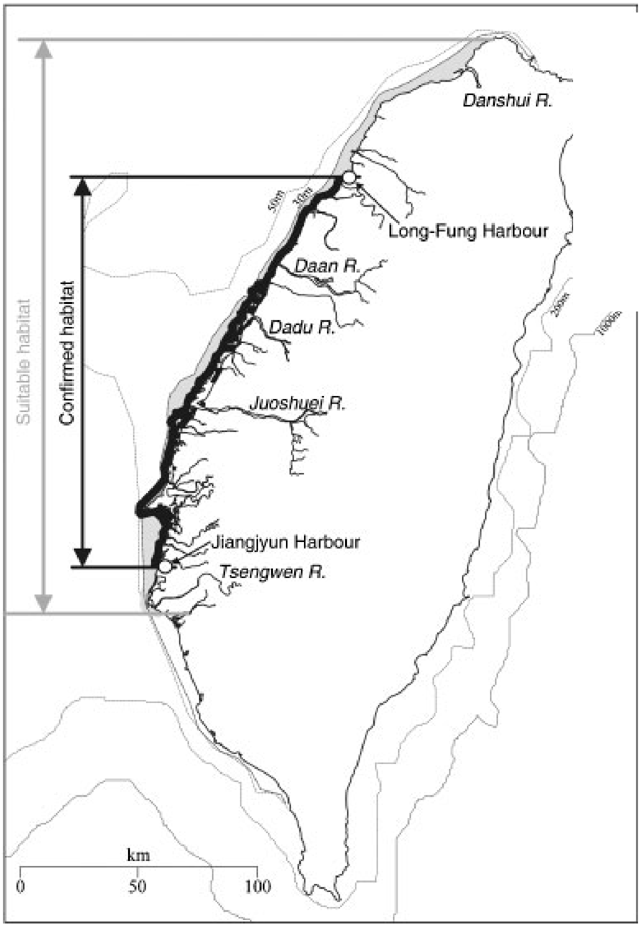

Figure 2: Priority habitat was designated for the Critically Endangered Taiwanese white dolphin as the coastal area comprising 'confirmed' and 'suitable' habitat by an expert panel convened by the ETSSTAWG (Ross et al. 2010). Legal protection of dolphin habitat is still pending under the terms of the Wildlife Conservation Act; in 2014, the Taiwanese government announced the intention to designate 'Major Wildlife Habitat' under the Act.

2.3. Threats

The five major, long-standing threats faced by the Taiwanese white dolphin are: fisheries interactions, habitat loss and degradation, reduction of freshwater flow to estuaries (with a concomitant reduction of important estuarine productivity), air and water pollution, and noise disturbance (Wang et al. 2007b; Ross et al. 2010; Dungan et al. 2011). The potential for windfarms to join, and exacerbate the impacts of, these major threats to Taiwanese white dolphins through cumulative, synergistic and cascading effects is a considerable challenge to the conservation of this small and declining population.

For example, of the four known stranded individuals of this subspecies, two (one in 2009 and one in 2014; see Wang et al. 2015, 2017b) were almost certainly killed by net entanglement. A large proportion (~58%) of photo-identified individuals bear serious injuries, many of which have been attributed to fishing gear (Wang et al. 2017b). A few known dolphins have also been observed and photographed carrying, or been seriously mutilated by, fishing gear (Slooten et al., 2013; Wang et al. 2017b; Wang and Araújo-Wang 2017) (Fig 3). Additionally, it has been estimated that the anthropogenic loss of just one individual from the Taiwanese white dolphin population every 7 to 7.6 years (Slooten et al. 2013) will lead to the extinction of the subspecies; two independent population viability analyses (PVAs) were consistent in predicting low probability of persistence (Araújo et al. 2014; Huang et al. 2014) without an adequate management response. One serious concern is that windfarm installation could displace fishers further into dolphin habitat. Therefore, the known impacts of fisheries interactions and the potential impacts from windfarm development could combine to accelerate the decline of the subspecies.

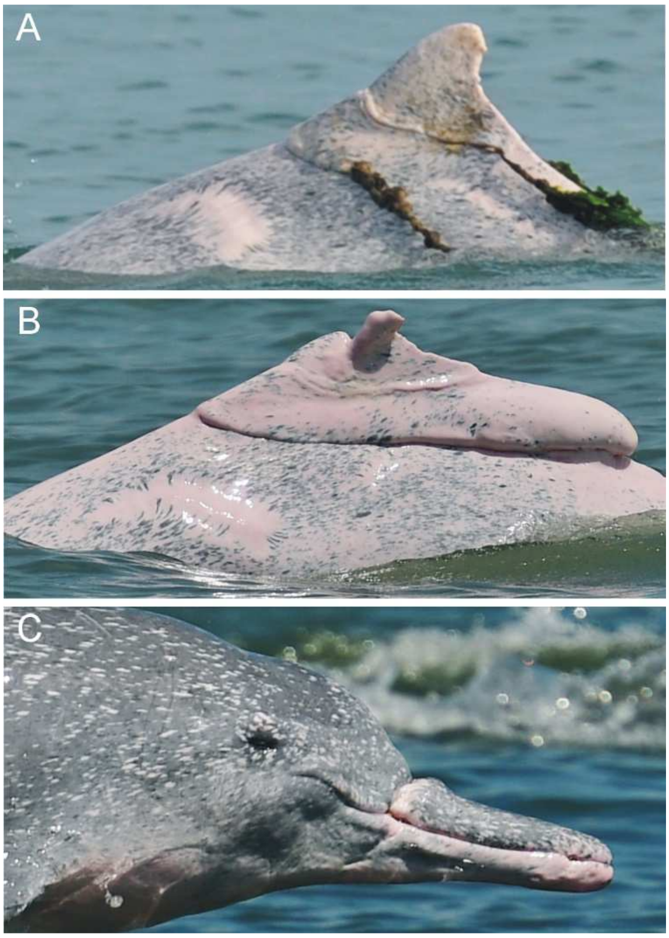

Figure 3: Photographs of (A) a nursing female Taiwanese white dolphin with fishing gear slowly slicing through her dorsal ridge and fin during the summer of 2012 and (B) her resultant massive injuries as observed in the summer of 2017; her calf in 2012 (C) also suffered injuries that were almost certainly due to fishing gear and possibly during the same event. (Photographs by J.Y. Wang courtesy of CetAsia Research Group Ltd.)

All studies of this subspecies have provided clear evidence that *any* additional human-caused mortality greatly increases its extinction risk. The proposed windfarms, given that they are planned to be in or adjacent to Taiwanese white dolphin habitat, thus pose a substantial risk to the subspecies.

3. Low Abundance and Restricted Range Make Taiwanese White Dolphins Especially Vulnerable to Threats

3.1. Conservation Risks for Small Populations with Restricted Ranges

The Taiwanese white dolphin is an example of a Critically Endangered cetacean with low abundance and restricted range. High site fidelity or contracted ranges due to habitat loss make such populations particularly vulnerable in general (Forney et al. 2017). Siting of windfarms in or adjacent to their home range therefore adds to the vulnerability of the Taiwanese white dolphin because they have no place to go.

Where populations with restricted ranges are concerned, genetic diversity and distinctiveness ('genetic' here includes not only genotype but also phenotypic characters such as morphology) and taxonomic status are also often relevant factors when assessing risk. In general, consultations with scientific authorities should be conducted with the aim of making evidence-based decisions using the most complete and up-to-date research available on the taxon in question.

As with all cetaceans faced with the three phases of windfarm development—construction, operation and decommissioning—Taiwanese white dolphins will be subjected to alterations of their habitat (Table 1). However, any negative effects of habitat alterations will have disproportionate impacts on Critically Endangered populations because they are unable to go elsewhere to avoid the threats (Forney et al. 2017).

3.2. Assessment of Disproportionate Risks

Risks from windfarms include, but are not limited to, noise disturbance, especially during construction and decommissioning; increased vessel traffic due to the need for support vessels; potential for contamination from the cleaning, operation and maintenance of the turbines; increased levels of contaminants and pathogens that may be released from the substrate by dredging and pile driving; and interactions with the fisheries sector due to displacement of the dolphins or fishing vessels into areas where greater overlap between fishing gear and dolphins occurs, such as might result from exclusion of fishing vessels within the footprint of the windfarm (Table 1; see also e.g., Bailey et al. 2014).

Environmental assessments for Taiwan's windfarm projects must consider the combined disproportionate risk to the Taiwanese white dolphin if they are to provide managers with adequate information with which to make decisions about offshore windfarms. The more typical considerations that take on additional importance regarding noise disturbance (e.g., Southall et al. 2007) include, *inter alia*:

- characterization of the species' existing acoustic space;
- determination of whether the species can hear the sounds generated by the three phases of windfarm installations (construction, operation and decommissioning); and

- an assessment of whether any acoustic characteristics of the animals' vocalizations or echolocation overlap with the sounds generated during the three phases.

Noise has the potential to cause temporary or permanent hearing loss (also known as temporary and permanent threshold shift or TTS and PTS, respectively), but also to mask important communication signals. In addition, it has the potential to displace animals from priority habitat (see Ross et al. 2011); however, see above regarding restricted-range cetaceans, such as the Taiwanese white dolphin, which have nowhere to go (Forney et al. 2017).

Regarding contaminants, disease, and fisheries interactions, considerations include whether the population has had a thorough health assessment; what information is known from necropsies of stranded animals or other recovered carcasses (e.g., those found in fishing nets); and any information on entanglement rates or other interactions with fishing vessels and gear.

Additional issues to consider with special care when dealing with restricted range cetaceans such as the Taiwanese white dolphin include the diel and other temporal and/or seasonal spatial patterns of the population. This has implications for mitigation, as there may be obvious times of day or year to avoid construction activity, such as when, for example, the area is used for feeding, breeding or migration (e.g., Nowacek et al. 2013). However, the extent to which these patterns may be present and useful to mitigation may be limited due to the population's restricted range.

In addition, small populations have (or will develop) low genetic diversity, which may, *inter alia*, lower their ability to withstand exposure to pathogens (Spielman et al. 2004; King and Lively 2012), which may be released from the substrate by pile driving. Small population size also decreases resilience to natural and anthropogenic stochastic events (e.g., Lande et al. 2003), including those that could result from windfarm installation, such as an oil tanker colliding with a turbine leading to an oil spill, which could accelerate the extinction of restricted range populations.

Finally, windfarm installation could have indirect impacts on the Taiwanese white dolphin, particularly related to their feeding ecology. Environmental assessments should consider the bioenergetic needs and foraging behaviours of a species and how windfarm installation might affect prey numbers and distribution (Bailey et al. 2014). Restricted range cetaceans may have limited or specialized diets (e.g., Ford et al. 2010) and if windfarms alter the composition of fish assemblages by, e.g., introducing hard substrates (the turbine bases) to a soft seafloor (e.g., sand or mud) habitat, this could have a substantial impact on prey availability for the population (Table 1; see, e.g., Scheidat et al. 2011).

4. A Toolbox for Assessing Impacts

Guidelines for completion of environmental impact assessments (EIA) are available (e.g., IAIA, 1999). Globally, these regulatory reviews are intended to ensure human activities have minimal impacts on the environment. The proposed windfarms for the west coast of Taiwan are currently undergoing EIAs ('EIA' is used here generically and without reference to any specific legislation). These may be the first EIAs for such large windfarm development projects in and adjacent to a small, Critically Endangered population of cetaceans with restricted range, meaning a precedent is being set. These EIAs have raised serious concerns among researchers, local and international non-governmental organizations and the general public. As noted above, the need for ensuring that the responses to the standard questions posed in EIAs are suitably precautionary and take into account the special vulnerabilities of the Taiwanese white dolphin is critical if the subspecies is to survive into the near future as these windfarm projects proceed.

While the best practices designed for windfarm construction and operation in northern Europe may be a useful reference, there are important reasons to be concerned that they offer limited protection in the special case of the Critically Endangered Taiwanese white dolphin. It will be necessary to directly assess and monitor the impacts from windfarm construction and operation on this subspecies in the context of its particular vulnerabilities and develop a set of best practices that is specific for windfarm development in Taiwan.

Table 1: While best practices from windfarm projects in northern Europe, mostly in relation to harbour porpoises, *Phocoena phocoena*, and harbour seals, *Phoca vitulina*, offer important initial guidance, the extreme vulnerability of the Taiwanese white dolphin, because of its status as a small population of cetacean with restricted range, necessitates a different and specific local set of best practices. The decommissioning phase is not included in this table, as the impacts will be similar to construction.

	Operation/Activity *(impact)*	**Northern Europe harbour porpoises**	**Taiwanese white dolphins**
Construction	Pre-installation surveys, e.g., sub-bottom profiling, side-scan sonar *(noise)*	Limited concern, as impact range is small, thus displacement is limited	Heightened concern if it happens within or adjacent to dolphin habitat
	Dredging and deposition of material *(disturbance)*	Limited concern, as noise levels are relatively low and displacement thus limited	Heightened concern if it happens within or adjacent to dolphin habitat
	Pile driving *(noise)*	Central focus on hearing injury (TTS/PTS), mitigated through deterrence and methods such as bubble curtains. Displacement considered a cumulative effect across multiple wind farms	Central focus on non-auditory impact (NAI) arising from inability to move away from windfarm activities. TTS/PTS remain important for individuals. Heightened concern for mortality of prey species
	Sea floor alterations *(mobilization of contaminants)*	Considered of limited immediate concern, but there exists the potential to	Serious concern in polluted coastal waters where a high proportion of range is exposed

		increase food web bioavailability of sediment contaminants	
	Ship traffic associated with construction *(noise)*	Limited concern, as areas heavily trafficked already, i.e. increase in pressure is low	Additional traffic from windfarm support vessels may be of concern (should be studied)
	Ship traffic associated with construction *(vessel strike)*	Vessel strikes may be of concern	Vessel strikes, even if rare, are a concern, as every individual is important in this Critically Endangered population
Operation	Turbine operation *(noise/vibration)*	Limited concern, as the impact range is expected to be very low (tens of metres)	Likely of limited concern, but as even small habitat loss/prey reduction counts, it should not be ruled out without studies
	Service boats and ships *(noise)*	Limited concern, as areas heavily trafficked already, i.e. increase in pressure is low	Additional traffic from windfarm support vessels may be of concern (should be studied)
	Service boats and ships *(vessel strike)*	Vessel strikes may be of concern	Vessel strikes, even if rare, are an issue, as every individual is important in this Critically Endangered population
	Introduction of hard substrate *(prey abundance/distribution changes)*	Not considered a concern, as the loss of sea bed is minimal and artificial reefs can be seen as compensation for lost natural reefs in this area, as there is hard substrate habitat as well	Likely of limited concern, but as even small habitat losses count, it should not be ruled out without studies. Could be beneficial, but it could also be damaging if fauna of the current natural soft substrate habitat is changed and prey availability for the TWD is decreased. (Scouring could also be problematic if contaminated materials are used in construction and modifications to direction and strength of current flow cause habitat alterations)
	Changes to fisheries *(bycatch)*	Banning of bottom trawls considered beneficial. Displacement of gill nets usually considered neutral or beneficial	Changes to fisheries can have complex results. Must be considered in detail project by project

With this in mind, the following key concepts are essential tools when preparing or reviewing an EIA for windfarm (or other development) proposals in or adjacent to

Taiwanese white dolphin habitat, or indeed that of any small population of cetacean with restricted range:

- Conservation status and biology/ecology of species of concern
- Potential impacts from windfarm (or other development)
- Biophysical environment
- Technical specifications of windfarm (or other development)
- Mitigation and risk management
- Monitoring

Each of these concepts must be addressed with due consideration for the social, economic and political framework within which the EIA is being applied, and for ecological connections to international waters or those of other jurisdictions.

The overarching principle to apply when evaluating the following concepts is that even though data from abundant cetaceans with extensive range may be the best available, they may not apply to small populations of cetaceans with restricted range. Therefore, data specific to these small populations must be collected to form the basis for local best practices. Known effects on abundant cetacean populations with extensive habitat are likely to be of greater concern for populations with low abundance and restricted range (Table 1).

4.1. Conservation Status

To properly anticipate the diversity and severity of impacts that a local cetacean population will incur as a result of windfarm installations, the broader context of that population's current risk status must be determined. Compiled estimates for abundance, population trajectories and relevant demographic parameters (e.g., birth and mortality rates) should ideally be included as part of the EIA scoping process. For many cetacean species, including the Taiwanese white dolphin, such information is readily available from national and international risk status inventories such as the IUCN Red List of Threatened Species, and published peer-reviewed papers.

If a species or population is already established as satisfying criteria for high-risk classification (e.g., the 'threatened' categories of the IUCN Red List of Threatened Species: Vulnerable, Endangered, and Critically Endangered[3]), then significant adverse impacts from offshore windfarm installations in or adjacent to its habitat should be considered highly likely. As mentioned throughout the report, the vulnerability of small populations of cetaceans with restricted range, such as the Taiwanese white dolphin, means that any impact will be magnified. Therefore, any knowledge gaps should inherently be recognised as substantial concerns and treated appropriately. The grave consequences for the Taiwanese white dolphin following the loss of individual animals, or when experiencing negative influences on vital rates, means that lack of data needs to be handled in a precautionary way if the intention is to maintain a population that is viable in the long-term.

[3] www.iucnredlist.org

4.2. Potential Risks from Windfarms

Offshore windfarms pose multiple risks, which may change depending on whether the project is in the construction, operation or decommissioning stage (Table 1) and can have impacts on the entire range of the affected population. These risks can degrade habitat quality, which is particularly problematic when a population has a highly restricted range. Therefore, quantifying the percentage of Taiwanese white dolphin habitat that will be affected by windfarms is of key importance.

Windfarms can lead to direct habitat loss through the physical presence of the turbines. These structures represent a small reduction in the original habitat, which would be negligible for populations with larger ranges, but is a concern for the Taiwanese white dolphin. While the summed footprint of each turbine might be small, the particular arrangement of turbines can also lead to barrier effects, which could effectively remove a much larger section of habitat. Similar concerns about barrier effects were raised with regard to the Hong Kong-Zhu Hai-Macao bridge construction, which spanned across Chinese white dolphin (*Sousa chinensis chinensis*) habitat in Hong Kong's waters. Monitoring of dolphin movements using theodolite tracking before, during and shortly after construction showed differences in dolphin movement (Hung 2017); dolphins did not cross under the bridge, suggesting a large segment of habitat might be lost to them. However, it is not yet clear if these changes in movement are reversible in time after displacement by construction; continuing because these piles are spaced too closely (about 100m apart); or continuing due to other construction activities in the area. More data are needed to better understand the situation.

Installing windfarms may also result in shifts in human use of the habitat, such as fisheries and ship traffic. These disturbances could change the subspecies' distribution within its habitat, displacing animals from already limited resources and critical areas, as well as causing habitat degradation, fragmentation, loss of feeding/breeding ground, and reduction in ecological carrying capacity.

4.2.1. Noise

The strongest noise source associated with windfarms is impact or percussive pile driving during the construction phase (e.g., Erbe 2009). Cetaceans exposed to pile driving often change behaviour, including changing association patterns or showing avoidance (these are what we define as non-auditory impacts or NAI). They may actively avoid areas of their habitat (Kendall and Cornick 2016; Carstensen et al. 2006), although they may return when construction is complete (e.g., Scheidat et al. 2011). In addition, pile driving may mask acoustic signals that are important to these dolphins. It may also cause stress, as well as hearing loss (e.g., Nowacek et al. 2007; Weilgart 2007; Bailey et al. 2010; Tougaard et al. 2015). Noise can have similar effects on prey species, and if the availability of prey is reduced as a result of noise, then dolphins will experience indirect impacts (see also below, under 4.2.4., Displacement of fish and fishing). Taiwanese white dolphins may not avoid (or be able to avoid) pile driving disturbance, which could result in being exposed to high sound levels for long durations, which would increase the risk of experiencing NAI, TTS or PTS (Table 1).

Noise from work other than pile driving associated with the construction of windfarms, such as dredging and pre-installation surveys (using, e.g., sub-bottom profilers or side-scan sonars), could affect cetaceans unable (or with limited means) to avoid these sound sources due to their restricted range (see Table 1). Similar impacts may also occur during decommissioning if impulsive sources are used. Given the Taiwanese white dolphin's limited options for moving away, mitigations used must be of demonstrated effectiveness. Noise from support vessels during construction, operation and decommissioning may be of lesser concern, as the additional number of vessel transits and the additional amount of noise from support vessels are often expected to be small and temporary relative to pre-existing levels. However, additional vessels may be of greater concern if turbine construction is within the habitat of small populations of cetaceans with restricted range or if existing vessel traffic is light; therefore, risks from increased vessel traffic in the case of the Taiwanese white dolphin should not be dismissed without studies.

Noise from operational turbines is generally considered of little concern for large populations of cetaceans with extensive ranges, due to its low frequency and intensity and limited transmission distance (in the range of tens of meters) from a turbine (Madsen et al. 2006; Nedwell et al. 2007). However, operational sounds from turbines that are sited within dolphin habitat may increase the effective footprint of the turbines and further increase the total area of habitat lost to this restricted-range cetacean (Table 1). Furthermore, any chronic sound introduced into their habitat (especially by a large series of turbines, even if the sound produced is well outside their most sensitive hearing range and has a limited zone of influence) could have disproportionate impacts. Therefore, the risks operational sound poses should not be dismissed without studies.

4.2.2. Contaminants and pathogens

The resuspension of heavy metals, persistent organic pollutants (POPs) and other pollutants is another heightened concern (Eggleton and Thomas 2004). With chemical pollutants such as polychlorinated biphenyls (PCBs) binding to organic materials and fat molecules, there is a significant risk of enhanced bioaccumulation and biomagnification in the dolphin food web (see, e.g., Alava et al. 2012). The largest reintroduction of these materials into the environment would occur during the construction phase, from dredging and pile driving (Zucco et al. 2006). While POPs continue to be a threat to cetaceans in the North Atlantic region (see e.g., Murphy et al. 2015; Jepson et al. 2016), the primary source of these contaminants is unlikely to be substrate resuspended into the water column during windfarm construction. This is therefore considered of limited concern for harbour porpoises in northern Europe, where the proportion of the population exposed to resuspended pollutants is small (see Huthnance 1991 for a description of these conditions). In contrast, for Taiwanese white dolphins, this may pose a substantial concern, given its heavily polluted habitat with soft substrates that absorb and sequester contaminants coming from industry and sewage outfalls. It is not uncommon to encounter large groups (the largest reported was 41 – see Dares et al. 2014) of Taiwanese white dolphins, which means that any additional point source pollution within their restricted range may have impacts on a disproportionate number of animals (Table 1).

During operation, contaminants may be introduced through the scouring of any contaminated hard substrate (such as concrete containing coal ash) added to provide protection to the pile itself. Again, the large proportion of Taiwanese white dolphin habitat that might be affected by these contaminant sources is a substantial concern.

As noted above, sewage released into coastal waters in certain regions of the world is often minimally treated or untreated, meaning soft substrates in particular can harbour dangerous pathogens. These too may be released during construction, operation and decommissioning; Taiwanese white dolphins may have reduced ability to withstand such exposure (Table 1 and see 3.2., Assessment of Disproportionate Risk). However, all of these concerns may extend even beyond decommissioning, as the materials used as the base of the turbines may have an ongoing impact on the environment if they are not removed completely.

4.2.3. Ship traffic

During construction of offshore windfarms, vessel traffic generally increases, as support vessels move to and from the turbines being installed, although fishing vessels otherwise normally found in the habitat are often excluded. In many cetacean habitats, the addition of these support vessels does not appreciably increase the intensity of ship traffic, as such traffic may already be high. However, in the habitat of restricted range cetaceans, the loss of even one individual to a vessel strike is of critical concern. Therefore, the slight increase in risk of a support vessel striking a Taiwanese white dolphin carries more weight than with abundant cetaceans (Table 1). This risk may also be increased at night and recurs during the decommissioning phase.

During the operational phase, service and maintenance vessels will also be present on a routine basis; again, the increased risk of vessel strikes may be slight, but for the Taiwanese white dolphin, vessel strikes, even if rare, are an issue of substantial concern, as the loss of every individual will have a disproportionate impact (Table 1).

4.2.4. Displacement of fish and fishing

As noted above, the actual presence of the windfarm may alter the distribution and composition of fish assemblages by acting as an artificial reef (Scheidat et al. 2011) particularly in the soft substrate habitat of the Taiwanese white dolphin. While artificial reefs are often considered beneficial to a marine ecosystem by increasing the cumulative surface area of available habitat, they might attract species that are not dolphin prey and hence lead to an overall reduction in prey availability for these dolphins. Furthermore, noise during construction, and potentially operation, of a windfarm may also displace fish species in much the same way as it does cetaceans (Table 1; Popper et al. 2010).

Fishing activity may also be influenced by windfarms, as fishing vessels may either target the new fish aggregations and species (particularly problematic if dolphins are also drawn to them) or be excluded from the installation by the possibility of gear snagging on the various structures. The exclusion of fishing fleets from windfarms can also be mandated through no-vessel or no-fishing zones (Scheidat et al. 2011). This displacement may increase fisheries density in particular areas and exacerbate the effect of this threat on the dolphins, redistribute fishing activity in ways that lead to additional fishing pressure within dolphin habitat or create new or increased competition for already dwindling resources (Table 1).

Bycatch and net entanglements are a substantial concern for many small cetaceans, and one that may already be enhanced in association with noise exposures (Wright et al. 2013). Clearly, the consequences for Taiwanese white dolphins that any fishing redistribution represents is concomitantly of great concern, as even small increases in mortality risks can be catastrophic for this small populations. However, changes in the spatial distribution of fisheries are likely to be highly complex and regionally dependent (for example, if dolphins enter the footprint of an operational windfarm, their entanglement risk arguably decreases if fishing vessels are excluded), meaning that these changes would need to be assessed on a case-by-case basis.

4.2.5. Other risk-related issues

Regardless of the specific risk or benefit, it is necessary to understand the effects both on the individual and on the population. Immediate, individual effects may range from a brief cessation of important behaviour (e.g., foraging, socializing) to acute stress, TTS, PTS or even death in the most extreme cases. While the more severe of these impacts are likely to lead to immediate, short-term effects, subtler, chronic impacts may not become visible for years. Cumulative, synergistic and cascading impacts are also known to occur but are poorly understood. In addition, the long time frame over which windfarms are expected to operate raises the spectre of Taiwan's common and seasonal occurrence of natural disaster events (i.e., earthquakes and typhoons) that can damage turbines in ways that have impacts on dolphins (e.g., relatively frequent turbine damage will result in more servicing, repair or recovery of equipment that has fallen into the water). These stochastic risks need to be considered in planning phases and EIAs. Finally, uncertainty must also be taken into account; there are often data gaps that obstruct understanding of population level consequences. As a result, attempts should be made to model linkages between short-term changes in individuals and populations due to disturbance, to long-term changes in population dynamics and vital rates (e.g., King et al. 2015; Booth et al. 2017).

4.3. Biophysical Environment

To adequately assess the potential for impacts, an EIA should contain a description of the environment at the location of proposed offshore windfarm development. The extent of the environment considered by EIAs can be as small as the development site to hundreds of kilometres from the site. For the Taiwanese white dolphin, an EIA should encompass the entire known habitat of the population, even if the turbine sites are some distance from the borders of their range, as underwater sound can travel considerable distances from its source.

The physical, acoustic and biological characteristics of the environment should be described. In addition to these typical EIA elements, there needs to be a thorough description of other, pre-existing human activities within the combined areas of the windfarm and dolphin habitat, as synergistic, cumulative or cascading impacts from the addition of a windfarm to this already imperilled population's habitat become critical. These might include shipping channels, small-boat traffic, fishing, pollution or other industrial plants. Any of these might represent pre-existing stressors that will combine negatively with the new addition of windfarm-related stressors. Furthermore, the windfarm might affect these pre-existing activities and change (positively or negatively) the interplay of potential stressors. For example, the windfarm area might be closed for fishing, reducing bycatch at the windfarm site. Yet, as discussed above, fishing might be displaced into more inshore waters, hence drastically increasing the risk of dolphin bycatch.

Important physical characteristics to consider include oceanographic features such as bathymetry and meteorological/ocean parameters (e.g., salinity, temperature, turbidity, dissolved oxygen, chlorophyll-A), which are needed for sound propagation modelling and water quality assessments (DOC 2016; Gholizadeh et al. 2016). Also, currents, tidal flux and substrate composition (e.g., mud, sand), including contaminants or pathogens sequestered in the substrate, should be described (see above regarding resuspension of contaminants and pathogens).

There should be good coverage of baseline soundscape monitoring and/or modelling that quantifies the geophony (with contributions from wind, waves, precipitation, earthquakes—as relevant), biophony (with contributions, *inter alia*, from marine mammals, fishes and invertebrates) and anthrophony (e.g., ship noise) throughout all known dolphin habitat, as well as suitable habitat. Geospatial and temporal (diel, lunar, seasonal) patterns should be explained. This section in any assessment must justify the metrics chosen for the quantification and characterisation of the acoustic environment. Although different metrics might be necessary for the dolphins and their prey, all metrics used should be internally consistent.

The biological characterisation of the environment must also include a description of biodiversity (i.e., species other than the Taiwanese white dolphin), including more abundant and wide-ranging cetacean species inhabiting the waters off the west coast of Taiwan. Windfarm impacts on these other cetacean species may be less severe, but should not be ignored, especially since there are other cetaceans in these waters that are classified as threatened on the IUCN Red List (e.g., the narrow-ridged finless porpoise, *Neophocaena asiaeorientalis*, is Endangered; the Indo-Pacific finless porpoise, *N. phocaenoides*, is Vulnerable).

4.4. Windfarm Specifications

In addition to details on the biophysical environment, EIAs for windfarms should provide an overview of the different phases of the windfarm project (from geotechnical surveying, to construction, operation and decommissioning). Geotechnical surveying would typically be completed before the EIA for the windfarm is completed, and might include multi-beam sonars, side-scan sonars, coring and standard penetration testing, all of which could have an impact on the dolphins.

Whenever available, thorough descriptions should be made public regarding the machinery being installed, the number and size of turbines (e.g., height, wing span, power, activation wind speed), their geographic positions, installation schedule and the methods and equipment used to install them (e.g., impact piling, vibratory piling, suction piling, drilling). Making information available on the foundation type (including pile specifications such as geometry, dimensions, material, ground insertion depth and scour protection) is also important. Information previously released needs to be updated when changes are made, with these updates made public in a timely manner.

While fixed foundations (monopile, tripod, jacket) are the most common, there are some new types of floating foundations (spar, semi-submersible, tension leg platform) that should also be given serious consideration, as they may reduce certain impacts (e.g., no piling, sited in deeper waters). In addition to the actual turbines, the power grid will have to be installed and might include cable laying, dredging, onshore substation installation or more piling for offshore substation installation—all of which need to be quantified adequately in the EIA. Of primary concern is the spatial distribution of noise fields generated by the construction phase of windfarms, as this work often involves large vessels and pile driving systems that generate high levels of noise.

The temporal variation of the noise fields within the project area relates to the potential cumulative impacts on marine fauna. It will be important to know the duration of noise-generating work on each of the turbine supports, the schedule and location of the work, and the number of supports that may be installed simultaneously. Expected vessel locations and movements should be documented. These timing details should be discussed in relation to the overall project duration.

4.5. Mitigation and Risk Management

Once risks have been identified, measures to reduce impacts to the greatest extent possible should be considered, noting that this is a higher standard than the more commonly used 'as low as reasonably practicable' for more abundant and wide-ranging taxa. Similar distinctions have been made for seismic surveys in the habitat of the Critically Endangered western gray whale, *Eschrichtius robustus* (Nowacek et al. 2013). Early planning is key to addressing certain impacts that cannot be mitigated through any other means, such as redistribution of fisheries.

4.5.1. Construction phase

During pile driving in the construction phase, maintaining a safety or monitoring zone around the source (e.g., using visual observations, passive acoustics) is insufficient mitigation for the Taiwanese white dolphin, given its extreme vulnerability to habitat disturbance within its restricted range. Furthermore, the use of sound sources to deter animals from approaching the construction site (e.g., seal scarers, pingers, ramp-up/soft starts) is wholly inappropriate mitigation, and may even be harmful, as these are meant to displace animals away from the construction and Taiwanese white dolphins have nowhere to go (Forney et al. 2017). The focus should be on siting turbines farther from Taiwanese white dolphin habitat and reducing noise output as much as possible. Safety zone mitigation does not prevent widespread disturbance, which is a serious concern for Taiwanese white dolphins.

Measures to reduce noise exposure might include:

- Locating the greatest threats resulting from the turbines away from Taiwanese white dolphin habitat;
- Using multiple sound absorbers/scattering techniques (e.g., multiple layers of bubble curtains, cofferdam or combination of these);
- Carefully choosing construction methods (e.g., vibratory piling, suction, drilling)
- Considering foundation types (e.g., monopile, jacket, floating) and their configurations;
- Considering various options for operational timing, such as scheduling to limit simultaneous installations, synchronized breaks (quiet times), scheduling to keep levels low for a certain proportion of the time and/or at specifically important diel periods; and
- Enforcing speed restrictions for support vessels to 10 knots or less to reduce the chance of collision with dolphins within dolphin habitat as identified in Ross et al. (2011).

Also, it is important to note that operational mitigations only work if implemented correctly, and this will require focused real-time enforcement efforts that can respond immediately.

Finally, during construction, mitigation will be needed to minimise the resuspension of seafloor sediments and thus also pollutants and pathogens. Silt nets are often used, but in high current areas, they are likely to be ineffective because their effectiveness in low current areas are already suspect (Samuel Hung, Hong Kong Dolphin Conservation Society, pers. comm. November 2017); therefore, alternative methods should be considered.

4.5.2. Operational phase

During the operational phase, the main concern appears to be with the impacts of maintenance/service vessels, which can be reduced through the use of quiet vessels and optimal speeds to reduce noise and the likelihood of collision (see last bullet point above under 4.5.1., Construction phase). Operational noise from the turbines is of much lesser concern than construction noise (Madsen et al. 2006). However, its impacts should not be dismissed; they should be considered as part of the entire impact of the windfarms. This is especially true for small populations of cetaceans with restricted range. For example, if windfarm turbine presence can displace fishing activities that lead to increased threat to the dolphins, this benefit may outweigh the relatively minor impact of operational noise (see Petruny et al. 2014; wind turbines in North Atlantic right whale habitat may reduce vessel strikes, a major threat). Of course, this assumes that mitigation has been implemented appropriately and enforced effectively so that construction noise does not add greater threats to the animals. Operational noise from turbines would be best and most easily mitigated by siting turbines farther from Taiwanese white dolphin habitat (see first bullet point above under 4.5.1., Construction phase).

4.5.3. Decommissioning phase

At decommissioning (the cutting and removal of piles), mitigations for noise and resuspension of sediment would be similar to those used during the construction phase.

4.6. Monitoring and Adaptive Management

In addition to direct mitigation measures, broader management processes are needed to provide ongoing impact reduction to the greatest possible level. This will involve implementation of an adaptive management framework that would allow mitigations to be changed quickly (even during construction), potentially through amendments to the EIA, based on new information gained through (preferably long-term) real-time monitoring. Key performance indicators and any other measures to be monitored (before, during and for some time after) need to be carefully chosen to ensure that both impacts and mitigation effectiveness can be assessed properly.

Monitoring specifics might include, *inter alia*:

- Monitoring noise to keep levels below thresholds (which could be expressed as percent time thresholds are exceeded in all areas of habitat);
- Ongoing monitoring of water and sediment quality to ensure no loss of habitat quality; and
- Monitoring the dolphins during installation and operation (e.g., behaviour—noting the conclusions of Gomez et al. (2016)—distribution, health and even demographics).

Monitoring also raises the question of what conditions would trigger a stop-construction order, or any other management options. Likewise, threats to the turbines themselves (e.g., worst-case scenarios, such as earthquakes, tsunamis and typhoons—see 4.2.5., Other risk-related issues) will need to be considered and monitored, with details provided of repair, replacement and/or abandonment procedures, as appropriate.

More generally, it might be useful to review the best practices of other countries when developing the mitigation and monitoring section of an EIA, but implementing procedures should be tailored to the local situation as much as possible. Ensuring that all stakeholders have been consulted (including other industries, local residents, academics, scientists and NGOs) will help in identifying these best practices. However, it will also build 'social licence' for the project, provided that all stakeholders have been properly represented, consulted and given due consideration.

5. Wider Socio-Economic and Political Issues

All management and mitigation tools, including EIAs, will need to be considered in the context of the national, and potentially also international, legislative and regulatory landscape. For example, domestic regulations for EIAs might detail certain specific impact thresholds that cannot be exceeded. More broadly, social views and national policy will also play a role in how both the industry and the Taiwanese white dolphin are treated.

In the case of the Taiwanese white dolphin, many of Taiwan's initiatives for alternative energy arise from its commitment to phase out nuclear energy by 2025. As noted above, one part of this is a plan to install at least 3000 MW of offshore wind turbine energy by that same year. Depending on the energy production of each turbine (likely between 5 and 10 MW per turbine), construction activities for 600-1000 turbines and their associated cables, substations, anti-scouring facilities and so on, in and adjacent to the habitat of the Critically Endangered Taiwanese white dolphin, are being developed.

This initiative poses substantial challenges for Taiwan's Wildlife Conservation Act, under which all forms of 'disturbance' of the Taiwanese white dolphin are prohibited, as defined in Articles 3, 16 and 18[4]. In this context, the government has attempted to designate 'Major Wildlife Habitat', which to a large extent is contiguous with the areas planned for wind turbine construction, and acoustic energy from construction of wind turbines outside of the Taiwanese white dolphin's Major Wildlife Habitat will penetrate the habitat and can have harmful impacts on the dolphins. Also challenged is Taiwan's environmental impact assessment regime, which requires that all windfarms pass review by a committee that has the legal authority to reject any development project they believe will have unacceptable adverse impacts on the environment.

Conservation and environmental protection laws require implementation and enforcement, without which the principles are moot. Despite growing international attention and recognition, the Taiwanese white dolphin has been afforded only limited protections. Nonetheless, conservation advocacy groups have effectively used Taiwan's laws in major conservation initiatives; for example, the Kuokuang Petrochemical project was abandoned (New York Times 2011) and moved to Malaysia and the Formosa Steel Plant project was moved to Vietnam (R. Winkler, Wild at Heart, pers. comm.).

Windfarms affect more than cetaceans. For example, they represent a navigational hazard to shipping, which must be considered for human health and safety reasons during planning stages. Even if official shipping lanes remain unchanged, the movements of vessels will be somewhat constrained as a result of windfarm installation. Given the noise introduced into the ocean by shipping, such planning also represents an opportunity to incorporate environmental concerns into the deliberations (see Petruny et al. 2014). Any resulting changes may need to be approved by the International Maritime Organization, although precedent exists for such changes to be made to reduce environmental impacts on marine mammals[5].

[4] http://conservation.forest.gov.tw/EN/0001643
[5] http://sanctuaries.noaa.gov/news/press/2012/pr122712.html

Arranging the locations of two spatially overlapping activities represents rudimentary marine spatial planning (Ehler and Douvere 2007). This planning could be expanded to consider additional industries, such as fishing, to assess further opportunities to locate activities in ways acceptable to all stakeholders, while minimising collective impacts. It may even be possible to find ways to reduce impacts to the dolphins below current levels, a win-win scenario. An inclusive, transparent process of locating new, and relocating older, activities around each other and the dolphins often creates a sense of ownership in the resulting solutions. This would build social licence (see 4.6., Monitoring) and should lead to less resistance to the final decision. In turn, this increases certainty for each stakeholder and promotes cross-sector relationships and a more sustainable business model.

6. Discussion and Recommendations

There are many considerations for assessing and mitigating impacts of windfarms planned in or near Taiwanese white dolphin habitat that have not featured in the European experience to date. While efforts to protect primarily harbour porpoises from hearing damage in Europe have been typically appropriate, these protections have generally been achieved through certain noise dampening technologies and displacing the animals into other areas. The latter is a serious concern for Taiwanese white dolphins, which are unable to shift to equally suitable areas (Forney et al. 2017) and the above discussion details the appropriate consideration of this and various other factors specific to Taiwanese white dolphins. We recommend locating the greatest threats from windfarm installation away from priority dolphin habitat.

It should also be acknowledged that not all EIAs on small populations of cetaceans with restricted range will be able to follow these guidelines thoroughly or even adequately, due to lack of relevant data. Accordingly, while the guidelines discussed above are both to inform managers (or EIA reviewers) of data needs as well as alert them to data gaps, we urge application of the precautionary principle in these situations as the only means to ensure this small population does not suffer from any further declines (Wright and Kyhn 2015).

We also strongly recommend that Taiwanese government agencies and their consultants make all research and monitoring data on sound propagation from the test turbines in Miaoli and Changhua counties, dolphin monitoring during the test turbine installations and any other relevant activities related to the windfarm proposals and projects publicly available during the scoping and assessment processes. We also recommend that any planned research, monitoring and mitigation data that become available as windfarm projects proceed be made publicly available, and ideally any reports or assessments translated into English, to allow international experts to evaluate impacts.

We recognize that planning agencies consider mitigation for offshore windfarms (and other marine projects) based on threshold values—whether for approach distances or sound exposure levels or any other measure—the easiest to implement and enforce. Establishing a safety zone of so many metres or a maximum sound exposure level of so many decibels re $1 \mu Pa^2 s$ or even requiring ramp-up procedures may serve adequately for abundant cetaceans with expansive habitat into which they can move during construction or decommissioning. However, for small populations of cetaceans with restricted range, such as the Taiwanese white dolphin, threshold values used elsewhere are not reliable or sufficiently precautionary as proxies for impact and must be avoided. Once again, we urge Taiwan to proceed to develop local best practices that take into account the special vulnerabilities of Taiwanese white dolphins instead of using 'textbook' examples that were not developed for small populations of cetaceans with restricted range.

Finally, we strongly recommend that windfarm proponents pursue a novel and value-added partnership with fishers so as to protect dolphins wherever they be encountered. This would include dolphins in their habitat or dolphins that may be displaced by the noise and disturbance from windfarm construction or operations. Since both fishers and the dolphins may be displaced, it is vital that this not lead to an increased risk of entanglement in a more confined coastal area. The potential for a zone of heightened interaction and conflict between fishers and dolphins is real – avoiding this is critical to the recovery of the population. Windfarm proponents can play an important stewardship role for the Taiwanese white dolphin, thereby enhancing its green image and working actively to recover its population. If construction and operation of these offshore windfarms are done properly, these developments offer the promise of clean energy and increased domestic energy security in Taiwan, and hope for the Taiwanese white dolphin.

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