Recovery Plan for the Taiwanese White Dolphin (*Sousa chinensis taiwanensis*)

Prepared by

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EXECUTIVE SUMMARY

The goal of this recovery plan is to specify actions needed to stop the decline of Taiwanese white dolphins (TWDs), promote their recovery and ensure the long-term viability of these dolphins in their natural environment. TWDs are a subspecies of Indo-Pacific humpback dolphin endemic to a narrow strip of coastal waters along western Taiwan. Population size is currently estimated to be fewer than 75 dolphins and declining. TWDs are recognised as seriously endangered both nationally and internationally.

Available knowledge is sufficient to justify moving forward with six immediate actions:

1. Establish a ban on gill and trammel nets in TWD habitat.
2. Locate any new development and related impacts away from TWD habitat.
3. Establish mandatory routes and speed limits for vessels to reduce both noise and the risk of vessel strikes in TWD habitat.
4. Reduce pollution (air, water, soil).
5. Increase natural river flows.
6. Establish regulations to limit human-caused underwater noise levels in TWD habitat.

The ban on gill and trammel nets is the single most urgent action needed. If effectively enforced, it would immediately halt the decline in TWD population size. The other five actions may not have immediate effects, but are essential for sustained TWD recovery. Precisely because they require longer times to show effects, it is important to *initiate* the other five actions without delay. A long-term view of TWD conservation is essential because TWDs have a low natural rate of increase. For example, even if all human-related mortality stopped immediately, it would take at least a decade for the population to increase from 75 to 100 animals.

In addition to immediate government actions for TWD recovery, several research topics were identified as high priority, including monitoring trends in abundance and estimating survival and reproduction rates. Results from TWD research should be transparent and accessible to both local and international audiences.

Implementation of the priority actions are the responsibility of Taiwanese government agencies, but implementation steps could be detailed by a group of local and international stakeholders to be convened by the government. However, the current development of offshore windfarms provides an opportunity for a creative solution to the most urgent threat, bycatch in fisheries. Companies and financial institutions involved with windfarm development could contribute to government programmes to eliminate gill and trammel nets from TWD habitat by compensating fishers for a transition to other fishing methods. Such an innovative solution would be a win for windfarms and green energy, a win for fishers, and, most importantly, a win for Taiwanese white dolphins.

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1. BACKGROUND

A small population of Indo-Pacific humpback dolphins (*Sousa chinensis*) living in the shallow, turbid, estuarine waters of central western Taiwan was discovered by scientists in 2002 (Wang et al., 2004a). These dolphins comprise a population that is isolated geographically and genetically from those found in the neighbouring waters of China by the relatively deep waters of the Taiwan Strait (Wang et al., 2008). Because these dolphins were diagnostically different from other populations of the species, they were recognised as a subspecies, the Taiwanese humpback (or white) dolphin (TWD), *Sousa chinensis taiwanensis*, in 2015 (Wang et al., 2015) (see Appendix 2.A). The TWD is the only marine mammal that is endemic to the waters of Taiwan. Body scars on a large proportion of living (Wang et al., 2017) and stranded dolphins indicates that the most direct and immediate threat to this subspecies is bycatch in fisheries, particularly those using gill and trammel nets (see Appendix 4.A.i).

This recovery plan was prepared by 16 international experts (see Appendix 1) who participated in a 3.5-day workshop at the University of Western Ontario, London, Ontario, Canada from 28-31 August 2019, at the request of the Taiwanese non-governmental organizations (NGOs) Wild At Heart Legal Defense Association and Matsu's Fish Conservation Union. The participants included experts, on the TWD, cetacean biology and ecology, bioacoustics, and conservation policy, and representatives of Taiwanese and international NGOs and Taiwan's Ocean Conservation Administration. The primary objective of the workshop was to prepare a recovery plan specifying actions needed to stop the decline of TWDs and promote their recovery. The plan does not represent official positions of, or approvals by, any government agencies, although it identifies the relevant officials or agencies with responsibility for aspects of the conservation of this subspecies (see Section 2.E). Modifications to the plan may be required as new scientific information becomes available, the status of the TWD changes or goals and objectives of the plan are achieved.

As early as the first surveys for TWDs, it was clear that the population size was small and the animals occurred in a very restricted area (Wang et al., 2004b). It is now known that the entire subspecies numbers fewer than 75 individuals (Wang et al., 2012) and it appears to be on a declining population trajectory (Araújo et al., 2014, Huang et al., 2014) (see Appendix 2.C), which means that no level of additional human-caused stress (no matter how small) can be considered sustainable.

New development projects have increased public concern for TWDs. A proposed massive (4,000 ha) petrochemical plant in the middle of dolphin habitat—claimed at the time to be vital to Taiwan's economic survival—was cancelled because of great public pressure (see Appendix 4.A.ii). Nevertheless, large-scale development projects (e.g. expansion of existing large ports and liquefied natural gas (LNG) terminals) continue to be proposed in and near dolphin habitat.

Proposed offshore windfarm projects have become the most recent focus of concern (see Appendix 5). While these windfarms pose potential risks, they also present a unique and positive opportunity to protect and promote the recovery of TWDs. The developers can contribute to the compensation of net fishers whose livelihoods are jeopardised by the elimination of gill and trammel nets from TWD habitat. This will result in the industry gaining social license to build and operate; fishers receiving adequate compensation in return for switching to less harmful fishing methods or pursuing other livelihoods; and the elimination of the most direct and immediate threat to the dolphins (see Section 2.C and Appendix 5.D). It is rare in wildlife conservation for a solution to a problem to benefit the wildlife population *and* be in alignment with economic interests. However, this rare opportunity will be lost if the necessary actions are not taken quickly. As dolphin numbers decline, the cost of achieving population recovery increases greatly.

Detailed information on TWD biology, Taiwanese and international legislative frameworks and threats is presented in Appendices 2–5.

2. RECOMMENDED RECOVERY ACTIONS

2.A. Goals and objectives

Recovery plans for endangered species typically include research and monitoring recommendations. However, enough is already known about TWDs and the threats they face to justify moving ahead immediately with a series of actions, without the need for further research. Although Section 3 addresses the research and monitoring necessary for *sustained recovery,* it is essential that the recovery actions described in this section begin immediately to *halt the decline* of this small population.

The overarching conservation goal is to ensure the long-term viability and ecological functioning of TWDs in their natural environment. The immediate objective is to halt the current decline by eliminating the use of gill and trammels nets throughout suitable habitat (i.e. habitat with the ecological features found in confirmed habitat) of the TWD (Ross et al., 2010) (see Section 2.C and Appendix 4.A.i; Table 1). Such a ban could be implemented any number of ways, e.g. through an immediate ban on nets; a buyout programme with a firm closing date (after which all nets would be confiscated but without compensation); or the elimination of such nets in confirmed TWD habitat within three years and in all suitable habitat within six years. Fishers of a county who have already expressed willingness to accept a buyout and abide by a net ban could be selected as a “test case” for how the ban would be implemented, as a means of demonstrating to fishers of other counties how the ban (and compensation) would work. However, the complete elimination of these nets in confirmed TWD habitat *within* three years is the objective, regardless of implementation details. Implementation details could be elaborated by a stakeholder group with the relevant expertise (see Section 2.E).

The longer-term conservation objective is to increase the population to more than 100 individuals within 15 years after full implementation of the priority action items (see Section 2.C and Appendix 2.B.vi). This is a realistic objective given the biology of these animals and the estimated current population size, which is probably > 60 but < 75 individuals (see Appendix 2.C). An increase in population size to ≥ 100 would also result in downlisting the TWD’s International Union for Conservation of Nature (IUCN) Red List status from Critically Endangered to Endangered, which would be a notable positive achievement for Taiwan. The ultimate conservation objective is for the population to grow and expand into all suitable habitat, giving the subspecies a greater ability to withstand unusual, episodic or stochastic events in the future (whether natural or human-caused). Individual dolphins have been shown to move throughout the current range. Therefore, as noted in Appendix 2.D, any conservation strategy that protects only certain high-use portions of the habitat will fall short of meeting recovery objectives.

2.B. Overarching recommendations

It is essential that any management decisions the Taiwanese government makes to recover the TWD are based on the best available science. While gray literature may have important information for management, particularly if it is eventually to be subjected to the peer-review process, decisions regarding recovery would ideally rely on peer-reviewed, published results. In addition, when substantial economic costs and benefits are at stake, conflicts of interest and mischaracterizations of data are an ever-present danger. Reliance on faulty, biased or misrepresented data heightens the risk of making inadequate or misdirected management decisions that do not end up achieving the desired management objectives, and this risk is disproportionately large when the decisions affect an endangered species or subspecies with a very small population and a restricted range, such as the TWD (see Appendix 4.C).

In addition, adequate consultation between the Taiwanese government and international experts (see Section 2.E) is strongly recommended because efforts to enable small populations to recover often require diverse expertise. International cetacean and conservation scientists are willing to assist and participate in efforts to implement this recovery plan. As an example of ways to facilitate this participation, translating all relevant documents, including research reports and environmental impact assessments, into English will allow international experts to quickly assess the science upon which decisions are based, as well as to understand and assess the actions being taken to enable TWD recovery. Availability of key documentation only in Chinese has been an ongoing obstacle to useful and timely input by international experts on research and monitoring, governmental processes and management decisions.

In addition, financial institutions and the developers they finance should ensure that development projects comply with international environmental and social standards such as the International Finance Corporation Performance Standards on Environmental and Social Sustainability[1] and Equator Principles[2]. Financiers are in a unique position to use their influence to assist and encourage developers and national governments to promote responsible environmental stewardship, but to date this has not occurred in Taiwan.

This recovery plan does not address implementation in any detail (see Section 2.A). However, detailed steps and strategies will be needed, soon, to ensure timely and effective implementation and are the recommended focus of the proposed stakeholder group (see Section 2.E).

2.C. Priority actions

Six priority actions are needed to prevent mortality and/or enhance TWD population growth (Table 1); these actions are related to the primary threats facing these animals (see Appendices 4 and 5). Actions that maintain the status quo or that do not directly promote TWD recovery, including all current mitigation measures for ongoing human activities, were not

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[1] https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_handbook_pps

[2] https://equator-principles.com/

considered when identifying these actions. A structured expert decision-making exercise carried out at the Ontario workshop scored each action based on how quickly it would have a positive impact on the dolphins and on how large that impact was likely to be. Table 1 lists the actions in scoring order. These actions *all* must occur, but the first is *key* to ending the decline of the population.

While it is recognised that an effective gill and trammel net ban (Table 1) is crucial to stopping the decline of these dolphins, it is also important to *initiate* action immediately on all five of the other actions listed below. Unlike the gill and trammel net ban, the benefits to the dolphins of the other recommended actions will take time, in some cases decades, to be realised, but they will be essential to achieve sustained recovery.

Table 1. Priority action items considered essential for the recovery of Taiwanese white dolphins

PRIORITY ACTIONS
Establish a ban on gill and trammel nets in TWD habitat
Locate any new development and related impacts away from TWD habitat
Establish mandatory routes and speed limits for vessels to reduce both noise and the risk of vessel strikes in TWD habitat
Reduce pollution (air, water, soil)
Increase natural river flows
Establish regulations to limit human-caused underwater noise levels in TWD habitat

1. Establish a ban on gill and trammel nets in TWD habitat.

A complete ban on gill and trammel nets in the waters of nine counties along the west coast of Taiwan (i.e. within suitable TWD habitat; see Figure 1) is the only action that would have an immediate (no time lag) and definite effect because it would eliminate the most significant cause of serious injury and mortality. Without such a ban, not only will TWDs be unable to recover, but they will continue to decline.

2. Locate any new development and related impacts away from suitable TWD habitat.

Western Taiwan is one of the most highly industrialised coastal areas in the world. Land reclamation, ports, shipping, industrial plants, freshwater diversion from estuaries (e.g. dams), fisheries and now wind turbine installations have substantially degraded the subspecies' only known habitat. Unless the impacts from further development of this coastline occur farther away from TWD habitat—beyond 3 km from shore (Ross et al., 2010) (see Appendix 2.D and Figure 1)—reversing the decline in dolphin numbers will become less likely, even if human-caused mortality in fisheries ends.

3. Establish mandatory routes and speed limits for vessels to reduce both noise and the risk of vessel strikes in TWD habitat.

Since dolphins rely on sound to feed, communicate and navigate, noise from vessels should be reduced as much as possible (see e.g. Jensen et al., 2009). In general, noise reduction can be achieved through reducing speed, although some engines make more noise at slower speeds. In addition, as vessel traffic continues to increase, boats travelling at high speed may collide with dolphins. The zone where speed regulations are recommended is only in the first 3 km of shore (Ross et al., 2010), where TWDs are most likely to be found. This action item is necessary for ultimate and sustained TWD recovery.

4. Reduce pollution (air, water, soil).

Dolphins need a healthy environment in which to grow and reproduce, so reducing pollution is a necessary step to the full recovery of TWDs. Pollution means in water and soil (which can enter water through runoff), but also air, since dolphins are air-breathing mammals. It is recognised that pollution has many types and comes from many sources, so reducing pollution cannot be achieved quickly or easily. Reducing pollution is likely to occur in many small steps affecting many pollution sources, over a longer period of time.

5. Increase natural river flows.

Achieving recovery of TWDs will need positive population growth over a long time period. This isolated subspecies is restricted to shallow coastal waters with concentrations in or near estuaries, presumably to feed. River flow (and hence estuarine productivity) has been greatly reduced in western Taiwan and full recovery of the subspecies will be promoted by restoring the quality of all suitable habitat. Restoration is likely to take time to achieve and even more time to be reflected in the growth rate of the TWDs, but is nevertheless essential to achieve sustained recovery.

6. Establish regulations to limit human-caused underwater noise levels in TWD habitat.

Although the degree to which increased noise reduces dolphins' ability to feed and communicate likely varies across species and circumstances (context) (Jensen et al., 2009), noise has other impacts (e.g. increase in stress hormones; see Rolland et al., 2012) and these can affect birth and death rates and consequently the rate of increase (population growth). When it arises from construction, noise may also cause at least short-term displacement, i.e. make the dolphins avoid the construction sites. Population growth is needed to recover from a dangerously small population size and any threat that reduces growth is to be avoided.

2.D. Socioeconomic consequences of conservation actions

Industrial development along Taiwan's west coast during the past 50 years has not only had serious impacts on wildlife but has also displaced fishers and imposed heavy (though usually unquantified) social and economic costs on coastal communities. It is strongly recommended that focused efforts are undertaken by developers and the relevant Taiwanese government agencies (see Section 2.E, Table 2 and Appendix 3) to resolve fisher displacement issues with the fishing villages adjacent to prospective development sites and to ensure that affected individuals are fairly and adequately compensated for lost fishing opportunities (including full buyouts of gill and trammel net gear). Participants in the Ontario workshop did not have the expertise needed to address these issues, but the socioeconomic consequences of industrial development (even "green" energy development) and of regulatory actions taken to protect TWDs would ideally be acknowledged, assessed and addressed by the Taiwanese government and relevant experts.

2.E. Role of stakeholders

It is strongly recommended that a series of mandatory, issue-focused stakeholder meetings be convened or facilitated by the Taiwanese government, to promote collaboration on the implementation of the actions identified in Section 2.C. For some stakeholders, such as fishers, the government is likely to be the only entity with the authority to ensure participation. Such facilitated stakeholder meetings have been welcomed and productive in other jurisdictions, ensuring buy-in by those affected by the implemented actions, and would allow optimal coordination and collaboration to develop the most effective approach to the challenges ahead in recovering the TWD.

Active engagement, meaningful contributions and vigorous and sustained efforts by all stakeholders are essential for the successful implementation of this TWD recovery plan. Key stakeholders include local and international NGOs, local and international scientists familiar with TWDs and general dolphin biology and ecology, offshore windfarms and other industrial developers and their financiers, shipping interests, fishers and fisher associations (see Table 2 for a list of stakeholders identified as necessary to collaborate successfully in the implementation of this recovery plan). Experts in socioeconomic analyses are also vital and should be recruited to participate in these meetings. Strong leadership from central and local government agencies is necessary.

Table 2. Potential stakeholders—government councils and ministries (and their relevant agencies), industries, researchers, non-governmental organizations (NGOs)—who will need to cooperate and collaborate on the implementation of this recovery plan

POTENTIAL STAKEHOLDERS FOR RECOVERY PLAN IMPLEMENTATION	
Stakeholder	*Category*
Executive Yuan (Cabinet)	Central government
Environmental Protection Agency	Central government
National Development Council	Central government
Ocean Affairs Council (Ocean Conservation Administration, Coast Guard Administration, National Academy of Marine Research)	Central government
Council of Agriculture (Fisheries Agency, Forestry Bureau, Department of Irrigation and Engineering, Bureau of Animal and Plant Health Inspection and Quarantine)	Central government
Ministry of Interior (Construction and Planning Agency)	Central government
Ministry of Transportation and Communications (Maritime and Port Bureau and Taiwan International Ports Corporation)	Central government

Ministry of Education (National Academy for Educational Research)	Central government
Ministry of Science and Technology	Central government
Ministry of Economic Affairs (Bureau of Energy, Industrial Development Bureau, Water Resources Agency, State Owned Enterprise Commission)	Central government
Office of the President	Central government
Central and local parliament members (legislators and council members)	Central and local government representatives
County/City magistrates and other officials	Local government representatives
Windfarm developers (e.g. developers/investors/ subcontractors/insurance)	Industry
Taiwan Power Company and CPC Corporation	Industry
Fishers associations and influential individual fishers	Industry
Other industrial developers	Industry
Shipping interests	Industry
Sousa chinensis researchers	Taiwanese and international
IUCN Species Survival Commission Cetacean Specialist Group	International expert group
Taiwanese White Dolphin Advisory Panel*	International expert advisory group
Relevant socioeconomic experts	Taiwanese and international
Relevant conservation NGOs	Taiwanese and international
National Oceanic and Atmospheric Administration	US government agency

*Formerly the Eastern Taiwan Strait *Sousa* Technical Advisory Working Group (ETSSTAWG)

2.F. Enforcement

The infrastructure to implement a gill and trammel net ban currently exists in Taiwan (see also Appendix 3.A). The Coast Guard Administration, within the Ocean Affairs Council, is present in every port and, among other things, inspects each vessel that goes out of, and comes into, each port on a continuous basis. There are also numerous sentinel stations distributed along Taiwan's west coast, which allows the Coast Guard to monitor more or less the entire coast. Checking for the presence of prohibited gear could be added to the duties of Coast Guard port officials, while sentinel stations (along with regular patrolling by Coast Guard vessels) can monitor for illegal fishing, thus ensuring no nets are deployed within TWD habitat. The trawling ban that is currently in effect in TWD habitat has been ineffective primarily because the gear is merely *excluded* within ~5.5 km (3 nm) of shore, meaning the boats go out with the gear and enforcement must occur on the water. Thus the exclusion zone is often violated.

It is essential that all existing environmental laws and regulations are rigorously enforced by relevant government agencies, including a regime to supervise and monitor activities, with penalties of sufficient magnitude to deter violations. This process needs to be public and transparent.

Observations do not suggest that lost or discarded fishing gear is a significant factor in entanglement risk for dolphins along the west coast of Taiwan. In addition, there is a programme already in place for the collection of lost and discarded nets and line, including by citizen groups (which improves social investment in marine conservation), so enforcement of this programme is considered sufficient.

Protecting TWDs and their habitat will require the dolphins' conservation needs to become central in Environmental Impact Assessments (EIAs) for all development projects in or near the west coast of Taiwan, including upstream watershed areas. It also is important for the EIA process to be public and transparent, and scientific uncertainty to be explicitly acknowledged. Where such uncertainty is present, a precautionary approach would result in management decisions in favour of the dolphins, to avoid errors in judgment that could put the dolphins at greater risk than they already face.

Taiwan's Environmental Protection Administration (EPA), the agency in charge of the EIA process, is also obligated to monitor and supervise a developer's compliance with its EIA commitments (e.g. mitigation measures such as noise limits, marine mammal observers). This agency has a powerful statutory basis to compel the developers to strictly adhere to these commitments and may even go beyond their scope if, for example, information not available at the time of adopting an EIA is later presented. When violations occur, the EPA can order cessation of "development activities" until the developer demonstrates to the agency's satisfaction that it has brought the project back into compliance.

TWD recovery will be promoted if government agencies ensure that development companies and financial institutions follow international best practices (at a minimum) in their planning, construction and operations (see e.g. Appendix 5.C). This responsibility has special force in situations where development is sited in or near the only habitat of a small, endangered wildlife population, as is the case in western Taiwan. A good example comes from the active involvement of both energy developers and international banks (as well as an international team of independent scientists and several conservation NGOs) in an effort to conserve a small endangered population of gray whales in Russia (Martin-Mehers, 2016).

Generally, a recovery plan provides an implementation timeline, with details on when various actions are to be initiated, which agencies or stakeholders are responsible for initiating and pursuing them, which will enforce them, how long the actions must persist and when it is believed they will have an effect. This recovery plan provides some general information on the first and last points (see Sections 2.A and 2.C). However, it is recommended that the relevant Taiwanese government agencies, such as the Ocean Conservation Administration, establish such timelines as a matter of urgency. As noted in Section 2.C, it is imperative that all six of the identified action items in Table 1 be *initiated* immediately—the current status of the TWD, at fewer than 75 individuals remaining, requires prompt and effective enforcement of all recovery plan actions and current laws if the subspecies is to be saved.

3. RECOMMENDED RESEARCH AND MONITORING

Ten priority topics for research and monitoring related to TWD recovery efforts (Table 3) were considered necessary for the subspecies' sustained recovery, but were ranked by the Ontario workshop participants to help guide managers and funding agencies, based on the understanding that research resources are generally limited. Five of the topics were judged high-priority, four as medium-priority and one as low-priority. The one topic that was unanimously considered high priority was monitoring trends in TWD abundance. See Appendix 6 for additional details.

Table 3. Research priorities for TWD recovery

RESEARCH PRIORITIES	
Topics	**Priority**
Monitor trends in abundance	High
Estimate survival rates, reproduction rates and age structure	High
Conduct health assessments of living dolphins	High
Gain an understanding of behavioural responses to disturbance	High
Monitor changes in distribution, movement patterns and habitat use	High
Collect information on stranded animals (e.g. analyses of tissues)	Medium
Estimate the cost of a gill and trammel net buyout programme	Medium
Gain an understanding of TWD prey	Medium
Quantify soundscape in suitable habitat	Medium
Determine social structure and any changes over time	Low

Many of these research topics have been traditionally addressed with boat surveys and observation. However, theodolites and drones may be suitable technologies for data collection in some cases. In line with previous recommendations (Wang et al., 2007b) to encourage onshore dolphin watching, and given these technologies' lower potential for disturbance of this population, consideration should be given to the development of a network of shore stations for conducting research and public education where appropriate.

Research by individuals with relevant expertise on socioeconomic and human dimensions will be needed, particularly with regard to estimating the cost of a gill and trammel net buyout (see Section 2.D and Appendix 6). As a final recommendation, once a reasonable period (e.g. 2 to 3 years) has elapsed to ensure researchers' right to first publication, data from government-funded research on the TWD should be made publicly accessible.

4. CONCLUSION

The recent extinction of the Yangtze river dolphin, or baiji (*Lipotes vexillifer*), in China, the impending extinction of the vaquita (*Phocoena sinus*), a porpoise found only in the Gulf of California in Mexico, and the near-extirpation of the Māui dolphin (*Cephalorhynchus hectori maui*) in New Zealand, demonstrate how quickly populations of small cetaceans with restricted distributions can disappear once their numbers have fallen below 100. Incidental mortality in fishing gear (bycatch) was the primary factor driving these cetaceans to extinction or near-extinction. The threats to their existence were known for decades, but the lack of decisive actions to stop the threats resulted in precipitous declines. There is little doubt that unless a different course of action is taken to reduce the unsustainable but reversible threats in Taiwan, the TWDs will join them.

It is important to avoid viewing the plight of these dolphins as an isolated concern of little relevance to the everyday life of the people of Taiwan. As fellow mammals, the dolphins are sentinels of environmental health in coastal waters and estuaries, living as they do at the interface between land and sea. Stopping environmental neglect and abuse, and indeed reversing the trend towards deterioration and loss, is as urgent for the people and other organisms living along Taiwan's west coast and in the watersheds flowing into the Taiwan Strait as it is for the dolphins. By saving the dolphins, Taiwan can ensure the long-term ecological (and hence, economic) viability of its west coast and waters, for all the wildlife species that inhabit them, as well as its citizens.

APPENDIX 1: List of Workshop Participants

Co-chairs:

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4) Dr. Randall R. Reeves (IUCN Species Survival Commission Cetacean Specialist Group—Canada)

Participants:

5) Dr. Tim Gerrodette (Southwest Fisheries Science Center, NOAA, retired—USA)
6) Dr. Naomi A. Rose (Animal Welfare Institute—USA)
7) Dr. Lars Bejder (University of Hawaii at Manoa—USA)
8) Dr. Simon Bonner (University of Western Ontario—Canada)
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10) Ms. Katherine Chong (Wild At Heart Legal Defense Association—Taiwan)
11) Ms. Ting-Yu Kuo (郭庭羽, Ocean Conservation Administration—Taiwan)
12) Dr. Douglas Nowacek (Duke University—USA)
13) Ms. Erin K. Schormans (St. Mary's University and CetAsia Research Group—Canada)
14) Dr. John Y. Wang (CetAsia Research Group and Trent University—Canada; National Museum of Marine Biology and Aquarium—Taiwan)
15) Mr. Robin Winkler (文魯彬, Wild At Heart Legal Defense Association—Taiwan)
16) Dr. Bernd Würsig (Texas A&M University—USA)

APPENDIX 2: Biology of the Taiwanese White Dolphin

2.A. Taxonomy and zoogeography

Clear differences in pigmentation patterns between humpback dolphins from the waters off western Taiwan and those from the waters off mainland China (the Jiulong River and Pearl River estuaries) showed that the former was an isolated population (Wang et al., 2008). The separation was further supported by the fact that no "matches" were found between the photo-identified individuals in the two sides of the Taiwan Strait (Wang et al., 2008; Chou et al., 2013; Wang et al., 2016) and by apparent differences in social organization (Dungan, 2011; Dungan et al., 2016) and acoustics (Hoffman et al., 2017). Wang et al. (2015) used a larger dataset and applied a quantitative method (Patten and Unitt, 2002) to show that the Taiwan population satisfied the criteria for subspecies-level designation (Amadon, 1949). The new subspecies was named *Sousa chinensis taiwanensis* (Taiwanese humpback dolphin or Taiwanese white dolphin) to distinguish it from the nominate subspecies, *S. c. chinensis* (Chinese humpback dolphin or Chinese white dolphin). The TWD holotype (specimen number: NMNS-14812) is under the care of the National Museum of Natural Sciences (Taichung City, Taiwan).

The historical zoogeography of this species is probably more similar to that of coastal-dwelling terrestrial mammals than to oceanic marine species of the region. The ancestors of TWDs almost certainly originated from the coastal waters of mainland China. During the last ice age (about 17,000–18,000 years ago), much lower sea levels would have exposed a land bridge connecting Taiwan with the continent (see Voris, 2000) and created shallow waters that permitted the dolphins to cross the Taiwan Strait and colonise the waters off western Taiwan. The subsequent retreat of glaciers deepened the Taiwan Strait and allowed greater intrusions of oligotrophic waters from the Kuroshio Current and South China Sea, which together solidified the Taiwan Strait as a barrier to humpback dolphin movement. Isolation of the new immigrants to the eastern Taiwan Strait over several thousand years would have facilitated differentiation (Wang et al., 2015).

2.B. Life history

With few carcasses available for direct examination, an understanding of life history parameters for TWDs has been challenging and slow. Even with more specimens, data from dead, beached individuals can be controversial because the carcasses may not necessarily represent the life history parameters of living individuals. Furthermore, for small populations the number of animals sampled tends to be too small to produce precise estimates of certain parameters. Long-term photo-identification of individual dolphins has made it possible to estimate some life history parameters of the living population, and the sampled individuals can continue to provide useful information over many years into the future. Therefore, the precision of estimates should increase as data accumulate.

2.B.i. Sexual maturation

There is no published information on sexual maturation in TWDs and direct data from a long-term photo-identification project are limited to two females identified as very young calves and monitored until they produced calves themselves (J.Y. Wang, unpublished data). The ages of these dolphins when first seen with a calf were 11 and 12 years. Assuming a gestation of roughly one year, these females would have been sexually mature at 10 or 11 years. It is possible that these two females were sexually mature earlier but had not been impregnated, had failed pregnancies or gave birth to calves that did not survive long enough to be photo-identified. However, this age at sexual maturation is similar to what was reported by Jefferson et al. (2012) for Chinese white dolphin females in Hong Kong. The 11- and 12-year-old TWD females were almost entirely gray but with considerable amounts of light spotting. The colouration pattern of other sexually mature TWD females of unknown age is similar to these two individuals, which is different from that described for Chinese white dolphins in Hong Kong (Jefferson et al., 2012). There are no data on the age or colouration of males at sexual maturity and this information is difficult to obtain, as it is virtually impossible to determine in the field when males begin producing sperm. This is true for any species that lacks obvious secondary sexual characteristics such as a mane (lions) or an exceptionally large dorsal fin (killer whales).

2.B.ii. Calving interval

Mean calving interval for Chinese white dolphins in Hong Kong waters was estimated as 5.22 ± 3.98 (SD) years (Jefferson et al., 2012). Data from a long-term photo-identification programme in Taiwan, based on observing six calving intervals, suggest a 5- to 6-year reproductive interval (J.Y. Wang, unpublished data), similar to that found by Jefferson et al. (2012).

Chang (2011), Huang et al. (2014) and Chang et al. (2016) presented life history information using another dataset and found calving intervals varying from 2.90 ± 1.28 (SD) years to 3.52 ± 0.28 (SD) years. The low estimates from these studies were likely biased downward (i.e. underestimated) because the dataset spanned only 4 years, making it impossible to observe longer calving intervals.

A further potential source of bias when estimating calving intervals is that the mothers of young TWD calves are difficult to identify because calves are very difficult to recognise individually; are almost always found in groups with other mothers and calves; and calves may also have strong bonds with individuals other than their mothers (Dungan et al., 2016). Considerable long-term photo-identification and behavioural data, along with sound deductive logic, are needed for better identification of mother-calf pairs, as errors in assigning mother-calf relationships can greatly affect understanding of calving interval.

2.B.iii. Mother-calf association

Jefferson et al. (2012) reported that in Hong Kong waters, mother-calf association usually lasts about 24 months, but a few individuals associate for 3–4 years and, in one extreme case, for 9 years (probably the last offspring of the female). In Taiwan, the association period seems to be considerably longer (J.Y. Wang, unpublished data). No mother-calf pairs are known to have separated after only 2 years, and 3–4 years appears to be the minimum while most continue to associate for about 6 to 7 years. The longest-lasting observed association was also 9 years, again probably the female's last offspring. However, the apparent pattern of longer-duration mother-calf association in the TWD does not preclude mothers from having new calves. Females with a new calf have been observed being accompanied by their older offspring, who may contribute to the care of their younger sibling. Furthermore, given the small population size, there is a relatively high probability for independent young dolphins to be seen in a group that includes their mother, which would increase the chances of prolonged mother-calf associations to be observed.

2.B.iv. Reproductive output

Assuming a maximum life span of 40 years for females, age of first reproduction of 10 years and a calving interval of 5 or 6 years, the number of calves produced during the lifetime of an average female would be no more than 5 or 6 because a final birthing event at age 40 would be unlikely to lead to a successfully reared offspring. Preliminary indications also suggest that female TWDs may not reproduce for the last 5–10 years of their lives (J.Y. Wang, unpublished data) and thus lifetime reproductive potential would be further reduced by one or two calves. Furthermore, with cetaceans, calves of first-time mothers often have lower survivorship (see Wells et al. (2005) for a discussion of this phenomenon). Considering all of these factors, it is probably realistic to assume that an average female produces no more than 3 to 5 calves in a lifetime, and of course it is unlikely that all offspring survive to reproduce.

The mean observed number of births each year for the population (since 2007) is 2.0 (J.Y. Wang, unpublished data). However, there have been years when no births were recorded and the maximum number observed in a year was five (J.Y. Wang, unpublished data). These are minimum numbers, as more calves could have been born but died before being photographed. Nevertheless, it is apparent that TWDs have low reproductive potential, which makes them especially vulnerable to harmful human activities.

2.B.v. Survivorship

The mean apparent survival rate for individually recognizable dolphins (not including young calves) from 2007 to 2010 was 0.985 (95% CI=0.832-0.998) (Wang et al., 2012) and slightly lower from 2011 to 2013 at 0.978 (95% CI=0.92-0.99) (J.Y. Wang, unpublished data). Apparent survivorship is likely the same as, or very similar to, actual survivorship because this is a very small population where all individuals are known, with no new individuals being identified (with the exception of the recruitment of young calves). Therefore, the identities of recognizable individuals do not change over time; there is no immigration or emigration; and there is a high probability that all living recognizable individuals are photographically identified within 2 years.

2.B.vi. Maximum rate of increase

There are no data on maximum rate of increase specific to TWDs. However, Moore (2015) estimated intrinsic rate of increase and generation time for the genus *Sousa*. Overall, with variable figures used for final calculations of calving interval, survivorship, time of sexual maturity and reproductive lifetime, the rate of increase is low; only about 3% per year. This means that these dolphins can sustain very few deaths in addition to natural mortality. With no human-caused mortality, it would take the TWD at least 15 years to increase from about 65 to 100 individuals. Therefore, rapid recovery is impossible and it will take years (possibly decades) to confirm a significant and sustained shift in the population's trajectory.

2.C. Abundance and trends

From 2002 to 2004, boat-based line-transect surveys were conducted for TWDs throughout most of the waters along western Taiwan. Distance sampling analysis of the data produced a mean density in these waters of 19.3 individuals/100 km^2 and a point estimate of 99 individuals (total abundance), with a CV of 51.6% (95% CI=37–266) (Wang et al., 2007a). Despite the low precision, this estimate was adequate for assessing conservation status using the scientific criteria of the IUCN Red List. Mark-recapture analysis of photo-identification data collected from 2007 to 2010 resulted in more precise annual abundance estimates, with the highest being 74 (in 2010) with a CV of 4% (95% CI=68–80) (Wang et al., 2012). Preliminary abundance estimates for 2011, 2012 and 2013, using the same photo-identification mark-recapture methods, varied from 71 (2011) to 67 (2012 and 2013), with CVs varying from 3 to 4% (J.Y. Wang, unpublished data). These estimates (along with population modelling—see below) are consistent with a declining population. The annual photo-identification programme is ongoing.

Two independent Population Viability Analyses (PVAs) simulated population dynamics under different scenarios of impacts from bycatch mortality and habitat loss/degradation. Both PVAs pointed to a likely continuing decline. Araújo et al. (2014) showed the population declining under the present (baseline) scenario at about 3% per year, while the rates of increase determined by Huang et al. (2014) varied widely, from a strong decline to a moderate increase. However, the positive population growth rates in Huang et al. (2014) were likely due to an assumed high rate of reproduction arising from an unrealistically short calving interval (see Appendix 2.B.ii). Araújo et al. (2014) showed bycatch mortality (particularly when females were removed) had a larger impact on the population's vulnerability than habitat loss. However, these authors recognised that the full effects of habitat modification were likely underestimated because sub-lethal effects are poorly understood and so were not included. In contrast, based on different assumptions, Huang et al. (2014) concluded that habitat loss caused a greater impact than fisheries bycatch.

2.D. Habitat, distribution and movement

TWDs are confined to the nearshore waters along central western Taiwan; in some ways their distribution resembles that of a riverine species. They are generally found in higher densities in and adjacent to major estuaries and in waters 5 to 8 m deep, although they can be seen in waters less than 1 m deep. They are rarely seen in waters deeper than 20 m, except in shipping channels that have been artificially deepened (Dares et al., 2014). They are most often encountered within 1 km of shore. Their known distribution includes roughly 750 km^2, but their primary distribution occupies ~330 km^2 in a strip of water 110 km long, from about Tongshiao (Miaoli County) to Taixi (Yunlin County) (see Wang et al., 2017). Their confirmed habitat is between Longfung Harbor (Jhonggang River estuary) and Jiangjyun Harbor (Tainan City), with the exception of intertidal waters inshore of sandbars along the coastline of Changhua County (Wang et al., 2007a), out to about 3 km from the shoreline as defined in Ross et al. (2010). Suitable habitat appears to extend from slightly south of the currently confirmed distribution and all the way to the northern tip of Taiwan (Ross et al., 2010). Recent video evidence from waters off Taoyuan County (R. Winkler, unpublished data)[3] and survey data (Chou et al., 2019) have confirmed earlier suspicions that TWDs inhabit waters farther north, in suitable habitat identified by Ross et al. (2010).

Photo-identification data suggest that, despite decades of habitat degradation and loss due largely to land reclamation, the TWDs still use their entire range (Wang et al., 2011). There is no evidence that different individuals only occupy specific areas (Dungan et al., 2016). Movements can be fairly rapid across the TWD's range, which is small by cetacean standards. One animal covered a minimum distance of more than half the full range within 9 days. The average minimum linear home range of recognizable individuals is > 70 km, and their average minimum areal home range is > 175 km^2 (Wang et al., 2011; J.Y. Wang, unpublished data). Such mobility means that any conservation strategy that aims to protect only a portion (or portions) of the full range of the population, e.g. "foraging hotspots" (Karczmarski et al., 2017), will fall short of recovery objectives.

The highest observed densities of TWDs have been in the waters influenced by the Dadu River estuary (Dares et al., 2017) and there is no evidence of large seasonal movements (Wang and Yang, 2011). Even though considerable differences in water temperature and other environmental parameters exist between wet and dry seasons (Dares et al., 2014), the overall pattern of habitat use does not appear to differ seasonally. Using passive acoustic monitoring, fine-

[3] With video and sighting evidence from the waters of Taoyuan County and the municipality (formerly County) of Hsinchu, confirmed TWD habitat now includes these waters.

scale differences in habitat use by TWDs within an estuary have been linked to tidal cycles (Lin et al., 2013) and rainfall amounts (Lin et al., 2015). However, some caution is needed when interpreting relationships between acoustic detections and actual presence or absence of dolphins because the detection of dolphin echolocation clicks depends on behaviour and environmental factors.

2.E. Feeding ecology

Little is known about the feeding ecology of this subspecies. Direct observations of feeding dolphins showed a wide range of generally small (<~30cm), inshore, estuarine fish prey, including croakers, mullet, eels, herring and tiger perches. As with humpback dolphins elsewhere, neither cephalopods (e.g. octopus, squid) nor crustaceans appear to comprise a noticeable part of the TWD diet. Clear evidence of net entanglement and observations of dolphins feeding near nets (including behind trawl nets) suggest they may at least occasionally be drawn to forage opportunistically around fishing gear (Slooten et al., 2013). However, such interactions are not as frequent or predictable as those observed in Hong Kong's waters (Parsons, 1998; Würsig et al., 2016), where Chinese white dolphins fed behind bottom trawlers before trawling was banned there in late 2012.

2.F. Social structure and behaviour

Unlike most humpback dolphins, which generally have weak social associations in "fission–fusion" societies (Cagnazzi et al., 2011; Dungan et al., 2012; Jefferson, 2000; Karczmarski, 1999), the Taiwanese subspecies appears to form stronger, lasting relationships (especially mother-calf pairs) with no apparent segregation into distinct social communities (Dungan et al., 2016). Such social stability may seem unusual for the species, but it is not unknown (see e.g. Maputo Bay, Mozambique; Guissamulo and Cockcroft, 2004) and may be due to living in spatially restricted, resource-limited environments (Perrin and Lehmann, 2001; Lusseau et al., 2003; Mann et al., 2012; Möller, 2012;), with very few remaining individuals with which to associate and where long-term relationships facilitate transmission of important information that can improve fitness (e.g. related to feeding or rearing offspring). The estuarine ecosystem of western Taiwan was almost certainly more productive before the fairly recent, massive industrialization of the coast and its waters, so it is possible that the present social organization of TWDs is a result of human impacts on the animals and their habitat.

Mating and breeding behaviour of TWDs is poorly known. Mother-calf pairs occupy central positions in the social network, with the associations among breeding females creating a relatively stable social structure (Dungan et al., 2016). Calves appear to be reared together in groups containing mother-calf pairs and lone mother-calf pairs are very rarely observed (Dungan et al., 2016). Therefore, the size of groups is heavily dependent on the presence of mother-calf pairs. Adult dolphins without calves form small groups (~3 individuals on average), whereas groups with mother-calf pairs tend to consist of about 12 individuals, but groups of more than 40 individuals (i.e. more than half the population) have been recorded (Dares et al., 2014; Dungan et al., 2016).

APPENDIX 3: Legislative Framework and International Conservation[4]

3.A. Wildlife Conservation Act of Taiwan

In 1989, Taiwan's government enacted the Wildlife Conservation Act (WCA). Efforts are underway to amend the Act to provide explicit protection for endangered species. Under the WCA, humpback dolphins (*Sousa* spp.) are afforded the strictest level of legal protection. They are designated "protected wildlife" and are "not to be disturbed, abused, hunted [or] killed" (Art. 4 and 16). However, even at this highest level of protection, the WCA has proven thus far to be ineffective in reducing the known human-caused threats that are slowly but surely killing off these dolphins (see Appendices 4 and 5).

The WCA is administered and enforced by the Forestry Bureau, a unit within the Council of Agriculture. However, in 2018, with establishment of the Ocean Affairs Council (OAC), responsibility for marine wildlife was transferred to the OAC's Ocean Conservation Administration (OCA). The OCA is also the competent authority within the central government for controlling pollution under the Marine Pollution Control Act. The Environmental Protection Administration is responsible for managing and enforcing the environmental impact assessments required for all major development projects under the Environmental Impact Assessment Act. The OCA is the agency most directly responsible for marine mammals in Taiwanese waters. However, the Fisheries Agency (also under the Council of Agriculture) has responsibility for managing fisheries that threaten the TWD.

3.B. IUCN Red List of Threatened Species

In 2008, the TWD (then known as the Eastern Taiwan Strait subpopulation (= population) of *Sousa chinensis*) was added to the IUCN Red List of Threatened Species[5] as Critically Endangered (Reeves et al., 2008). This is the highest category of threat short of extinction and assigned only to taxa that are "facing an extremely high risk of extinction in the wild." A decade later, new information was considered and the TWD is now recognised as a subspecies and continues to maintain its Critically Endangered designation (Wang and Araújo-Wang, 2018).

3.C. Convention on International Trade in Endangered Species of Wild Fauna and Flora

The TWD, along with all dolphins in the genus *Sousa*, are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[6]. Appendix I taxa are considered to be threatened with extinction and are the most endangered of those listed under this trade agreement and thus are subject to the strongest restrictions in international trade.

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[4] Taiwan (officially the Republic of China to the central government) is not recognised by most countries and is considered by the United Nations (and the IUCN) to be a "province of China." Nevertheless, Taiwan has economic and trade relations with every major country, and the central government, including the parliament, executive and judiciary, is independent of China.

[5] www.iucnredlist.org

[6] www.cites.org/eng/app/appendices.php

3.D. Convention on Biological Diversity

China is a signatory to the Convention on Biological Diversity[7] (CBD) and the Taiwan Strait Protected Region is included in the China National Biodiversity Conservation Strategy and Action Plan (2011-2030), which could benefit the conservation of the TWD. Although not a separate party to the CBD, Taiwan developed and approved a National Biodiversity Action Plan in 2001 and revised it in 2007[8]. The theme "Ecological Civilization: Building a Shared Future for All Life on Earth" is set to frame the 2020 UN Biodiversity Conference, to be held in October in Kunming, Yunnan Province, China.

3.E. United States Endangered Species Act

In 2018, the TWD was listed as Endangered under the US Endangered Species Act (ESA) after animal and conservation non-governmental organizations petitioned for such a listing[9]. The ESA provides conservation measures for species listed as Endangered (or Threatened), including the development and implementation of recovery plans[10]. For extraterritorial species, the ESA requires the Secretary of Commerce to encourage foreign countries to provide for the conservation of listed species and the entering into international agreements to provide for such conservation.

APPENDIX 4: Main Threats to Taiwanese White Dolphins

4.A. Existing major threats

In 2007, a panel of experts reviewed hundreds of potential threats and identified five main categories of human-caused threats facing TWDs. These existing major threats are summarised below. In addition, the fact that TWDs number fewer than 75 individuals is itself an additional threat (see Appendix 4.C), because such low numbers amplify existing threats, as well as introduce new ones specific to small populations.

4.A.i. Fisheries interactions

Of the five existing threats, fishing is the most direct and immediate threat to these dolphins (Ross et al., 2010; Dungan et al., 2011; Slooten et al., 2013; Araújo et al., 2014; Wang et al., 2007a,b; 2017). Gill and trammel nets are the predominant gear, with thousands being used throughout dolphin habitat (Dungan et al., 2011; Slooten et al., 2013). Other gear such as trawl nets and hook-and-line methods are less likely to kill dolphins (Slooten et al., 2013), especially because trawlers are banned from fishing within ~5.5 km (3 nm) from shore, which encompasses most of known TWD habitat.

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[7] https://www.cbd.int/intro/default.shtml; https://www.cbd.int/information/parties.shtml.

[8] http://www.swan.org.tw/docdir/NYBK1V0WIX.pdf .

[9] https://www.federalregister.gov/documents/2018/05/09/2018-09890/endangered-and-threatened-wildlife-and-plants-final-rule-to-list-the-taiwanese-humpback-dolphin-as.

[10] For more on how NMFS develops ESA recovery plans, see https://www.fisheries.noaa.gov/national/endangered-species-conservation/recovery-species-under-endangered-species-act.

Almost 60% of TWDs have serious injuries due to human activities (Wang et al., 2017). More than 31% of TWDs have been photographed carrying fishing gear or were likely injured by fishing gear (Slooten et al., 2013), with some incidents resulting in extreme mutilation (Wang and Araújo-Wang, 2017). It is important to note that these numbers underrepresent the impacts of interactions with fishing gear because they include only the animals that survived. At least two of the four stranded TWDs examined to date had clear evidence of entanglement in gill or trammel nets that likely resulted in, or contributed to, their demise (Dungan et al., 2011; Slooten et al., 2013; Wang et al., 2017).

Slooten et al. (2013) estimated 6,300 fishing vessels operate from the ports of the six counties comprising confirmed TWD habitat. Of these, ~45% are often fishing in coastal waters (within ~22.2 km/12 nm). A trawling ban exists for the waters inshore of ~5.5 km/3 nm, but some illegal fishing continues due to lax enforcement (Dungan et al., 2011; Slooten et al., 2013). There may also be resource competition between fisheries and dolphins (Pan et al., 2016). Overfishing may be partially responsible for the emaciated condition of some dolphins (Dungan et al., 2011) in years when the quality or quantity of prey is insufficient (Slooten et al., 2013).

4.A.ii. Habitat degradation and loss due to development

The west coast of Taiwan has high human densities and has been rapidly industrialised in the past century (Williams and Chang, 2008). Between 1995 and 2007, 20% of TWD habitat was lost as the coastline was altered by erosion and for flood control, fishing ports, power plants and other public facilities (Wang et al., 2004b, 2007b). To relieve pressures on agricultural and residential land needs, multi-purpose industrial areas were built over coastal waters (i.e. through "land reclamation" or terraforming), directly reducing and degrading dolphin habitat (Wang et al., 2004b, 2007b). As of 2007, 59 large-scale industrial projects were underway or already completed (including the Mailiao Industrial Park, Changbin Industrial Park and Taichung Harbour; see Figure 1). At that time, at least 20 other industrial developments were planned or being constructed and at least 80 others were under consideration for approval (Wang et al., 2007b).

In April 2011, a 4,000 ha petrochemical complex that was proposed for the nearshore waters of southern Changhua County near the north shore of the Juoshuei River estuary was cancelled after several years of planning. If this development project had proceeded, it would have destroyed about 7% of confirmed TWD habitat, while at the same time increasing overall underwater noise, petrochemical-related shipping traffic, air and water pollution and consumption of already strained water supplies from local rivers. The cancellation was a positive step for TWD conservation, but there are still many projects being proposed, including massive windfarm development in and adjacent to TWD habitat (Appendix 5), expansion of the Taichung port for an LNG facility, expansion of several power plants along the coast and construction of a large LNG facility (Liou et al., 2017) in Taoyuan on land and waters of suitable TWD habitat where there have been recent sightings. The planned construction site of this last project is also controversial because a unique reef system that contains at least one endemic species of crustose coralline algae is found only in this small area. These projects can further compromise the quantity and quality of the remaining TWD confirmed and suitable habitat (Araújo et al., 2014; Wang et al., 2007b).

With so little habitat available, it is clear that any further loss or degradation of remaining habitat will accelerate the subspecies' demise. However, even if no additional habitat is lost or degraded, *recovery* will require the protection of all remaining suitable habitat and the restoration of lost habitat (through increasing natural river flow wherever possible; see Appendix 4.A.iii). Restoration of estuarine habitat will be needed to allow the population to reverse the current downward trajectory.

4.A.iii. Reduction of freshwater to estuaries

Reductions in freshwater flow probably affect TWDs mainly through reductions in estuarine prey. Several major rivers along the west coast of Taiwan have been diverted in the upstream sections to provide water for agriculture, industry, power generation and household use (Taiwan Water Resources Agency, 2015; Wang et al., 2004b; Williams and Chang, 2008). The extreme difference in rainfall between the wet and dry seasons (Williams and Chang, 2008) further exacerbates freshwater reductions, because there may be little to no flow during the dry (winter) season when the dolphins are most likely challenged by food resources.

4.A.iv. Chemical pollutants (air, water, soil)

Coastal regions bordering TWD habitat have a wide variety of industrial complexes, including petroleum oil storage facilities, petrochemical plants, harbour-fuelling stations and thermal (coal) power plants (Wang et al., 2007b). Such facilities discharge pollutants into the local air, water and soil, which affect the quality of habitat for TWDs and their prey.

Presently, little is known about the impacts of chronic exposure to contaminants on TWDs. Ingestion of contaminated prey is the main vector for exposure to pollutants, but the dolphins also inhale air-borne contaminants in an area where air quality is frequently extremely poor and are exposed to water-borne contaminants through their skin (Ross et al., 2010). Heavy metals and persistent organic pollutants are of particular concern because they can accumulate in tissues to levels that can compromise health (Haraguchi et al., 2000; Simmonds et al., 2002).

The results of a study that modelled the burden of polychlorinated biphenyls (PCBs) in TWDs showed that a large proportion of the dolphins were above the PCB threshold limit where immune functions of other marine mammals are affected (Riehl, 2012). Possible suppression of the immune system in these dolphins is of great concern because the ability of individuals to endure all the other threats would be further compromised (Riehl, 2012).

TWDs may already be showing signs of immune deficiency, with 37% of the individuals exhibiting skin conditions that have been linked to water salinity and/or temperature and contaminants in common bottlenose dolphins, *Tursiops truncatus* (Yang et al., 2013). Furthermore, a large proportion of the animals was also found to have severe spinal anomalies (lordosis and scoliosis) (Weir and Wang, 2016). Whether the latter afflictions are related to contaminants, or to some other factor such as genetic issues, is unclear.

4.A.v. Noise

There is no direct information about the impacts of noise on TWDs, but also no reason to believe that TWD reactions are different from those of other members of the genus *Sousa*, especially *Sousa chinensis* (Piwetz et al., 2015). TWDs are subjected to many human-caused sounds, including those from vessels, military exercises, seismic research and percussive pile driving (Ross et al., 2010). Some of these sources can produce sounds that are extremely loud and potentially injurious (Würsig et al., 2000). Prolonged exposure to intense noise can lead to temporary or permanent threshold shifts in hearing (Mooney et al., 2009). Less intense human-caused sounds can affect the dolphins by inducing physiological stress; obscuring biologically-important sounds (even without shifts in hearing thresholds), such as those needed for communication, navigation or detection of prey (Nowacek et al., 2007; Wartzok et al., 2004; Wright et al., 2007); causing changes to their swimming behaviour (Ng and Leung, 2003; Piwetz et al., 2012); altering their acoustic signalling behaviour (Van Parijs and Corkeron, 2001a,b); and displacing them from important habitat (Götz et al., 2009).

A study on the underwater soundscape at two sites within TWD habitat suggested that even though shipping intensity along western Taiwan is relatively high, the noise produced by large vessels at these two sites did not appear to overlap much with the dolphins' whistle frequency range up to 6 kHz and vessels that generated higher frequency noise did not contribute much to the soundscape (Guan et al., 2015). However, hearing and vocalization ranges are not necessarily the same and obscuring sounds outside the dolphins' vocalization range could affect their abilities to hear predators or oncoming vessels. It is unknown if and how noise at higher frequencies (especially from vessels with smaller engines) affects the dolphins—the audible frequency range for humpback dolphins is up to at least 152 kHz (Li et al., 2012).

4.B. Additional/new threats

There are other and new human activities in TWD habitat, as well as threats emerging globally, that have the potential to negatively affect these dolphins. A non-comprehensive list includes: the development of boat-based dolphin watching tours off the west coast of Taiwan; the introduction of high-speed ferries (which may increase both acoustic impact, with their higher-frequency engine noise, and risk of ship strike); and emerging diseases (which may have a disproportionate impact on this declining, small, restricted-range population; see Appendix 4.C). These potential threats will need to be carefully monitored, to ensure they do not replace or add to the threats this subspecies already faces. However, these *potential* threats are of distant secondary importance when compared to the *immediate* threats affecting TWDs. If the existing major threats are not effectively addressed now, future and lesser threats are irrelevant.

4.C. Vulnerability of small and declining populations

When animal populations decline in numbers, they normally respond with mechanisms that allow the population to increase and return to the original size. For example, birth rates and/or survival rates may increase. However, if a population reaches a critically small size, these mechanisms may fail or even reverse. The TWD population is approaching, and may already have reached, that critical level. The fact that the entire subspecies exists as a single population confined to a small range means it is exceptionally vulnerable to a single catastrophic event such as a chemical spill, extreme weather, a disease outbreak or a harmful algal bloom (e.g. a so-called "red tide").

The mechanisms that occur at very low population sizes and increase the risk of further decline can be grouped into three effects:

(a) Socioecological effects can occur if the small population size affects cooperative feeding, calf rearing or group reactions to predators. At low population densities, individuals may have difficulty finding a mate. Given the small range of TWDs, finding a potential mate should not be a problem for them.

(b) Demographic stochasticity refers to the variability of annual population change arising from random birth and death events at the individual level. This variability increases when the population is very small (e.g. <100 individuals), putting the population at added risk of extinction or extirpation.

(c) Genetic factors can reduce the fitness of individuals and therefore influence the sustainability of a population through inbreeding depression and the loss of diversity due to genetic drift (Frankham, 2005; Reed, 2005). Specifically, in small populations like that of the TWD, the influence of genetic drift overrides that of natural selection, and can therefore result in the increase in frequency of deleterious alleles and the decrease in frequency of beneficial alleles. The combined effects of inbreeding depression and genetic drift in small populations can result in reduced survival and fecundity of individuals and thereby substantially increase the risk of extinction/extirpation (O'Grady et al., 2006).

APPENDIX 5: Offshore Windfarms as a Threat to Taiwanese White Dolphins

5.A. Scale of project overview

The proposed offshore windfarm developments have a long-term target to supply about 3,500 MW by 2025; an additional 5,000 MW is now planned by 2030. As of August 2019, two turbines and the base structures for 20 more have been installed offshore of Miaoli County. The projects will entail installation of at least 1,000 turbines, the majority of which will be in waters that overlap, border or will affect TWD habitat, including the areas with the highest dolphin densities (Dares et al., 2017; Figure 1).

5.B. How are offshore windfarms a threat?

Offshore windfarms pose multiple risks, which may change depending on whether a project is in the construction, operation or decommissioning stage (Ross et al., 2018). These risks can degrade habitat quality, which is particularly problematic when a population has a highly restricted range.

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 TWDs. While the summed footprint of each turbine might be small, the particular arrangement of turbines can create a barrier that interrupts free movement, in effect removing, or at least removing the animals' access to, a much larger section of habitat. Similar concerns about barrier effects were raised with regard to construction of the bridge linking Hong Kong, Zhu Hai and Macao, which crossed Chinese white dolphin habitat in Hong Kong. Monitoring of dolphin movements using theodolite tracking before, during and shortly after construction showed that the dolphins did not cross under the bridge, suggesting that a large segment of habitat was lost to them, at least temporarily (Hung, 2017).

Windfarms can also result in shifts in human use of the dolphins' habitat, such as fishing and ship traffic. If fishing effort is displaced away from the vicinity of the windfarms and into nearshore habitat, this could both increase the dolphins' risk of entanglement in gill and trammel nets and reduce their food supply because of competition with intensified fishing.

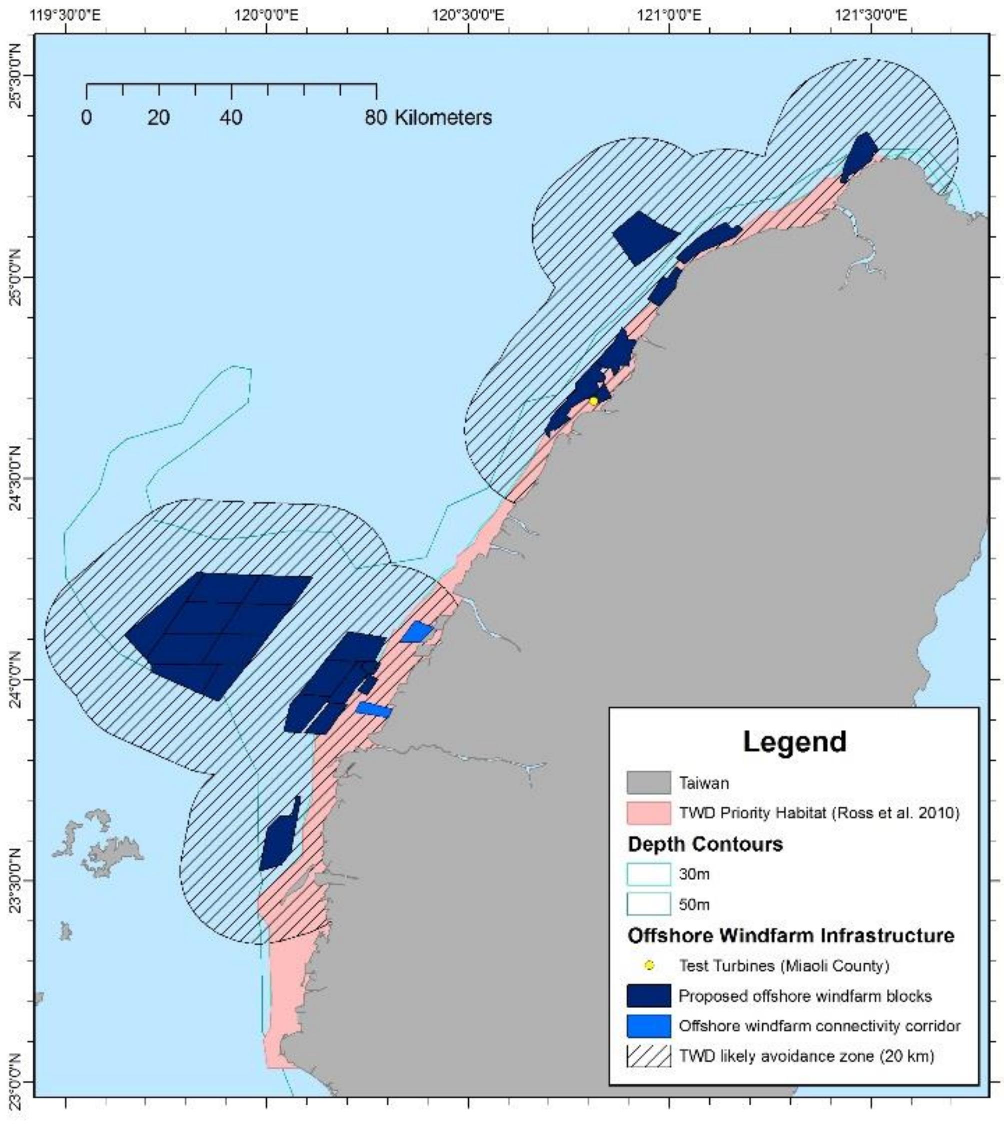

Figure 1. The location of proposed windfarm blocks and designated suitable habitat of the TWD and the 20 km zone within which noise from construction of the wind turbines (if unmitigated) can affect dolphins and other cetaceans (figure taken from Ross et al., 2018). Windfarm blocks that overlap with and are closest to suitable TWD habitat are of particular concern, as standard noise mitigation techniques may not be sufficient to prevent negative impacts, e.g. from percussive pile driving.

5.C. Why it cannot be business as usual with Taiwanese white dolphins

Given that this small and extremely vulnerable dolphin population has such a restricted range and "nowhere [else] to go" (Forney et al., 2017), it is strongly recommended that the management of human activities within the entire range of TWDs be precautionary and especially stringent. The mitigation measures to which the windfarms have committed thus far do not consider the possibility that the dolphins will be excluded from parts of their habitat or experience increased stress from disturbance. Windfarm mitigation to date has focused only on preventing direct injury or mortality, but this is insufficient when the population literally cannot escape sub-lethal impacts.

It is imperative that management of human activities within TWD habitat follow best practices for endangered species (Hawkins et al., 2017). For example, in Hong Kong, most of the construction activities in waters within the core range of the Chinese white dolphin no longer use percussive pile driving, but instead use combinations of vibratory/hydraulic "pushing," hydraulic hammering or bored piling, considered to be less disturbing (B. Würsig, personal observation).

5.D. The "win-win-win" solution

The single most pressing threat facing TWDs is fisheries bycatch (see Appendix 4.A.i). Eliminating gillnets to protect endangered marine mammals is a difficult problem worldwide. However, Taiwan has good governance, an established infrastructure for effective monitoring and enforcement (along its entire coastline) and an active Coast Guard (see Section 2.F). These key elements could make Taiwan the first jurisdiction globally to overcome this problem for an endangered marine mammal—a major accomplishment in marine conservation.

A creative solution is needed *and* possible. Good corporate environmental stewardship by windfarm developers can help to solve the bycatch problem. Companies and financial institutions involved with offshore windfarm development (which is already underway) could contribute to government programmes to eliminate gill and trammel nets from TWD habitat. While this investment would be large, developers already must compensate fishers for lost fishing opportunities. The additional cost of a net buyout is only a small fraction of the potential revenue from windfarm energy production and the benefits to the developers (see below) are anticipated to outweigh the costs.

This is an opportunity for the windfarm developers to help mitigate and offset harmful effects caused by their construction and maintenance activities and by providing an immediate benefit to this critically endangered mammal. The developers win, through resolving their conflicts with the fishing community, gaining social license, confirming their "green" reputation and blunting criticism. The fishing community wins, through receiving adequate compensation while fishers make the transition to new sources of income, switch to less environmentally harmful fishing methods or take early retirement. This should also reduce the negative attention directed at fishers because of their inadvertent role in driving the dolphin population decline. Most importantly, the Taiwanese white dolphins win, as they no longer die or get seriously injured in gill and trammel nets, their population decline halts and other actions to promote their recovery can move forward effectively.

APPENDIX 6: Research and Monitoring

As noted in Section 3, the participants at the Ontario workshop identified 10 research topics and ranked them as high, medium, and low priority.

1. Monitor trends in TWD abundance

Information on trends in abundance is fundamental to understanding the status of a population. Population trajectory (increasing, declining or stable) provides one of the most direct and easily understood metrics for assessing and communicating a population's status and progress toward recovery. In general, there are two approaches for obtaining abundance estimates with cetaceans: line transect-distance sampling analysis and mark-recapture analysis of photo-identification data. With small populations, the high precision possible using photographic identification makes the latter the monitoring tool of choice. This topic was unanimously considered high priority.

2. Estimate survival rates, reproduction rates, and age structure

The abundance of a population is directly dependent on the number of births and deaths. Thus, knowing survival and reproductive rates (including calving intervals) is important for understanding population trajectory. Information on age structure of a population is also very important for understanding the stability of a population over time. These are key pieces of information that can also help in modelling the population's status into the future. This topic was considered high priority.

3. Conduct health assessments of living dolphins

For small, isolated populations of long-lived, slowly reproducing species that are critically endangered, like the TWD, it is important to obtain information that can explain why living individuals might be compromised. The importance of studying living TWDs is emphasised because stranded individuals may not be representative of the living population. Health assessments of living TWDs are a high priority as they can provide relatively rapid snapshots of individual health. Some approaches for assessing the health of free-ranging cetaceans include: body condition assessments through photogrammetry (via SLR cameras and unmanned aerial systems, i.e. drones), visual and photographic observations (e.g. of skin lesions, biotic infestations, scars and injuries) and stress hormone and contaminant load analyses of tissue sampled by remote biopsy techniques (although this invasive technique is not recommended for the TWD until the population has shown signs of recovery; Wang et al., 2004b, 2007b).

4. Gain an understanding of behavioural responses to disturbance

It is important to gain a better understanding of the behavioural reactions of TWDs to sources of potential disturbance, in both the short and long term. Without such knowledge, it is not possible to predict, for example, at what frequency (pitch) and decibel level (loudness) certain underwater sounds will disrupt foraging, change movement and speed patterns, cause social disruption such as separation of mothers and calves or cause long-term avoidance of areas that are important for life functions.

Some behavioural changes can be predicted from research on the Chinese white dolphins in Hong Kong, especially but not limited to studies by Parsons (1998), Ng and Leung (2003) and Piwetz et al. (2012, 2015). However, the potential for behavioural disturbance of TWDs has not been investigated. Such disturbance could take various forms and be caused by noisy vessels, industrial activities and pile driving for windfarm installation. The general increase in various human activities on and along the highly industrialised west coast of Taiwan may itself constitute a non-point source of disturbance.

Behavioural reactions to disturbing stimuli can be studied in various ways. These can include making observations from a research vessel, theodolite tracking from shore (probably the best method, as there is no possibility of the research vessel's presence influencing the dolphins' behaviour), and the use of drones. Sophisticated analyses and statistical techniques are available to describe behaviour before, during and after potentially disturbing events, and these must be applied to ensure unbiased and statistically valid results. Because animals of the same species may respond differently to acoustic and other disturbing stimuli depending on their population history, demographic state and environmental context, behavioural response research on TWDs should be seriously considered (particularly if it utilises disturbances already present in the environment, as opposed to deliberately introducing disturbances). This topic was considered high priority.

5. Monitor changes in distribution, movement patterns and habitat use

Distribution and changes in distribution over time are closely related to habitat use and movement patterns. Habitat use, which is reflected in movement patterns (which may be seasonal or diel), forms the basis for a population's distribution over the long term. Changes in movement patterns and habitat use may be a consequence of human activities and in many cases may indicate disruption of important behaviours, as well as displacement from preferred habitat (e.g. feeding areas). Understanding how individuals in a population move within and use their habitat can be informative for management of human activities, especially when the population faces a variety of human-caused stressors. Continuing surveys show that TWDs still use the entire range of confirmed habitat (see Appendix 2.D) and additional surveys outside the current main distribution confirm that TWDs also use suitable habitat (as identified by Ross et al., 2010) (see Appendix 2.D). Several individuals have been observed to transit through the majority of confirmed habitat within 9 days (Wang et al., 2011).

Boat surveys that employ photo-identification can also contribute to information on distribution and changes in distribution if a population's full range (or nearly so) is surveyed. Data from dedicated line-transect surveys (i.e. without the need for photo-identification data collection) provide information on distribution as well. A better understanding of movement patterns and habitat use during low light periods (dusk to dawn), when visual studies are ineffective, can be obtained with passive acoustics studies. With year-round data collection, seasonal differences in movement can be obtained. Increasing these kinds of data (e.g. photo-identification combined with locational data) can help to better understand the flexibility (or lack thereof) of TWD movement. Very importantly, detection of changes in distribution, movement patterns and/or habitat use may be more rapid than detection of trends in abundance. This topic was considered high priority.

6. Collect information on stranded animals (e.g. analyses of tissues)

Important information can be gained from analysing tissue samples obtained from stranded individuals. To date, only a handful of TWD carcasses have been recovered after strandings. However, little to no information on these carcasses has been made public. Various analyses can provide a wide variety of important information, including pollutant loads, life history parameters, diet, genetics, ecology, sex and morphology. This research topic was considered only medium priority because of, among other things, the small number of specimens available for research, the uncertainty of representation of stranded individuals to the living population and the condition of the tissue samples obtained from decomposed carcasses.

7. Estimate the cost of a gill and trammel net buyout programme

Many fishery buyouts have occurred globally, but it is important to know the socioeconomic costs of such a programme, which are currently unknown in this case. It will be important for the Taiwanese government to immediately engage experts capable of estimating these costs, with financial help from the companies and/or financial institutions involved in windfarm development (see Appendix 5.D). Notwithstanding the need for a credible estimate of buyout costs, the process of eliminating gill and trammel nets from TWD habitat should begin without delay and be completed within three years (see Section 2.A).

8. Gain an understanding of TWD prey

Many fish species have been observed in the mouths of TWDs, but little is known about the importance (e.g. diet composition, seasonal availability, nutritional value) of possible prey species. About 10 TWDs have stranded and their carcasses been recovered over the past two or so decades. Of these, many had empty stomachs while others were nearly so (but note that the stomach contents of stranded individuals can represent a biased sample of the population for a number of reasons). Furthermore, there are few detailed studies of the diet of *Sousa* species. From what is known, TWDs seem to follow the typical *Sousa* pattern, feeding on a diversity of fish species; cephalopods appear to be of little or no importance.

With so few TWDs remaining, even if researchers were able to sample the entire population instantaneously, this would be unlikely to represent the nutritional needs of a healthy population (e.g. age-sex class differences, seasonal requirements). Some “skinny” animals have been observed in past years (see Slooten et al., 2013), but this appears to vary with year. Without stronger evidence that TWDs are facing nutritional stress, understanding what TWDs consume and the biology of their prey was deemed to be only a medium priority research topic.

9. Quantify soundscape in suitable habitat

Marine mammals rely heavily on sound to carry out critical life functions, such as communication, navigation and foraging. As such, it follows that any noise added to their environment has the potential to affect their short and long-term behaviour and/or cause masking of important acoustic signals. Over the past few decades, human-caused noise in the oceans, generated through e.g. shipping, oil and gas exploration and naval activities, has increased significantly (Frisk, 2012). Current and proposed industrial developments (e.g. windfarms, LNG terminals) within and adjacent to TWD habitat will cause significant changes to the background sound levels in their environment. Understanding the soundscape within TWD habitat (and how natural and artificial sound sources might influence it) was deemed a medium priority because other threats were considered to have more immediate impacts.

10. Determine social structure and changes over time

Different kinds of social structures can be affected differently by human activities. For example, animals that are solitary or in small groups may be less disturbed than subgroups that are variable in composition and size and whose inter-group communication might be impeded by acoustic disturbances. Social structure in different areas and with different population numbers within the *Sousa* species complex can be quite variable (see Dungan et al., 2012; 2016).

Nevertheless, knowledge of social structure and how this may be affected by human-caused disturbance is an important part of research and monitoring efforts. For social structure evaluations, ideally researchers wish to know the sexes and approximate ages of dolphins that travel within the same group, the duration of time they travel together and apart, familial relationships and how any of these parameters change as a result of human activities in their habitat. Methods for studying social structure include photo-identification and direct observation (including proximity analysis), as well as genetic analysis. Social structure information ideally also includes paternity information, but these data are generally difficult to collect in cetaceans, at least in the short term.

In general, social information requires intensive data collection efforts and extensive analysis, often spanning generations (i.e. multi-year timespans)[11]. This research topic therefore was considered of low priority, although data addressing this issue should be collected routinely every field season.

[11] However, some social disruptions can happen quite quickly, such as separation of mother and calf, and these can be observed soon after they happen.

DEFINITIONS OF TERMS

Allele—a variant form of a gene

Biotic infestations—pests or parasites living in great numbers in or on a host organism

CI—confidence interval, a range of values so defined that there is a specified (usually 95%) probability that the value of a parameter lies within it

Crustose coralline algae—heavily calcified algae that, like corals, contribute to the growth and development of a reef's structure

CV—coefficient of variation, a standardised measure of dispersion relative to the mean

Diel—referring to 24 hours of a day

Distance sampling analysis—a statistical method used in wildlife studies to estimate abundance and density, based on the distances of detected organisms from a point or transect line

Endemic—native; found nowhere else

Fission-fusion—social organization in which the size and composition of the social group change over time; individuals merge into a group (fusion)—e.g. sleeping in one place—or split (fission)—e.g. foraging in smaller groups during the day

Genetic drift—change in allele frequencies by chance over time

Gray literature—papers or reports that have not been subject to outside peer-review

Heterozygosity—the condition of possessing different alleles of a gene or genes within an individual

Holotype—a single specimen that represents a species when it was being described

Line-transect surveys—a type of sampling in which the positions of organisms are recorded relative to a transect line. Data from line-transect surveys are used in distance sampling analysis to estimate abundance and density

Nominate—originally recognised subspecies when a species is split into at least two subspecies (wherein the original species name is repeated twice, as in *Sousa chinensis chinensis*)

Oligotrophic—describing a region of ocean with very low productivity

Oceanic—relating to the open ocean (not coastal)

Photogrammetry—obtaining size measurements of objects using photography

Photo-identification—identifying individual organisms through the use of photography (often using natural markings, e.g. scars, colouration patterns)

Population—a group of individuals that are more likely to interbreed with each other

Stochastic—unpredictable or random

Zoogeography—past and present geographic distributions of animal species

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