Sustainable Fisheries and the Conservation of the Critically Endangered Taiwanese White Dolphin (*Sousa chinensis*)

An expert workshop held in Tainan and Taipei (Taiwan), April 28-May 2 2014

Under the auspices of the Eastern Taiwan Strait *Sousa* Technical Advisory Working Group

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Summary

A small, isolated and distinct population of Indo-Pacific humpback dolphins (*Sousa chinensis;* referred to locally as 'Taiwanese white dolphins' or TWD) inhabits the shallow, coastal waters of the Eastern Taiwan Strait. Deemed *Critically Endangered* by the IUCN in 2008, this population of fewer than 75 individuals is under assault from anthropogenic threats including air and water pollution, freshwater diversions from the estuarine portion of their habitat, noise and disturbance, habitat loss arising from intertidal areas reclaimed for industrial development, and fisheries interactions. Fisheries interactions were the focus of two expert workshops held in Taiwan under the auspices of the Eastern Taiwan Strait *Sousa* Technical Advisory Working Group (ETSSTAWG). Almost 65% of the population bears serious scars or injuries, most of which can be attributed to fishing nets and/or lines. Illegal trawling activities, coupled with unregulated gillnet and trammel net fisheries, present direct and indirect threats to these dolphins. We report here on the 2014 expert workshop, and recommend that Taiwan ban all gillnet and trammel net fishing inside the habitat of the dolphins, compensate those fishers seeking to exit the fisheries to embark on alternative livelihoods, transition fisheries to alternative (more dolphin-friendly) fishing techniques, and enforce the decades-old ban on trawling within 3 nm of shore. Immediate action on these recommendations, as well as actions to mitigate the other threats, offers hope of a recovery for this population. We recommend that the government of Taiwan consider implementing these recommendations well beyond their proposed TWD 'Major Wildlife Habitat', so as to include their full known current range and avoid edge effects which can increase the risk of extinction. The workshop suggested a management target of recovering the population to 100 dolphins by the year 2030, which would mean that the population met the criteria for improving its IUCN Red List status from *Critically Endangered* to *Endangered*.

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Introduction

The shallow, nearshore waters of the eastern Taiwan Strait are home to a small, isolated population of Indo-Pacific humpback dolphins that was discovered scientifically in 2002 (Wang et al. 2004). More recently, this population has been described as a sub-species of the Indo-Pacific humpback dolphin and named the Taiwanese White (or humpback) Dolphin (*Sousa chinensis taiwanensis*; Wang et al. 2015).The Taiwanese White Dolphin (TWD) population has been designated as 'Critically Endangered' by the IUCN (Reeves et al. 2012) and is estimated to have 74 individuals (Wang et al. 2012). Significant anthropogenic threats to the population include air and water pollution, freshwater diversions from the estuarine portion of their habitat, noise and disturbance, habitat loss arising from intertidal areas reclaimed for industrial development, and fisheries interactions.

The Eastern Taiwan Strait Sousa Technical Advisory Working Group (ETSSTAWG) was established in 2007 to provide a forum to offer science-based conservation advice in support of recovery of this small cetacean population. Comprising 17 leading national and international marine mammal and habitat experts, this group has i) convened a series of expert workshops, ii) reviewed major development project proposals for dolphin habitat, iii) advised government agencies in Taiwan, iv) provided media and conservation groups with updated information, and v) published scientific articles in the international literature. In 2010, the group proposed boundaries for the designation of 'Priority Habitat' (akin to 'Critical Habitat' elsewhere and 'Major Wildlife Habitat' under the Conservation Act in Taiwan), which comprised the total known current range of the dolphins as well as adjacent 'suitable habitat' (Figure 1; Ross et al. 2010). Guidance on the designation and implementation of protection measures for this 'Priority Habitat' is outlined elsewhere (Ross et al. 2011).

In late April of 2014, the Government of Taiwan proposed the designation of 'Major Wildlife Habitat' for the dolphins, with boundaries encompassing four counties along the west coast. The proposal does not capture the known current range of the dolphins, and very limited protection measures are poorly described. The ETSSTAWG submitted a comment to the agency responsible for 'Major Wildlife Habitat' in Taiwan (the Forestry Bureau) during the 30 day public consultation on this designation (May 2014). However, the announcement signals a significant change within the Taiwanese government, and opens the door to science-based advice and dialogue on dolphin ecology, habitat, threats to population viability, and the implementation of best practices as a means of reducing or eliminating such threats.

The ETSSTAWG recommends that the proposed 'Major Wildlife Habitat' be implemented immediately, but that mitigation measures be applied to the entire 'Priority Habitat' identified in Ross et al. (2011), and that 'Major Wildlife Habitat' be expanded as soon as possible to incorporate the entire 'Priority Habitat'.

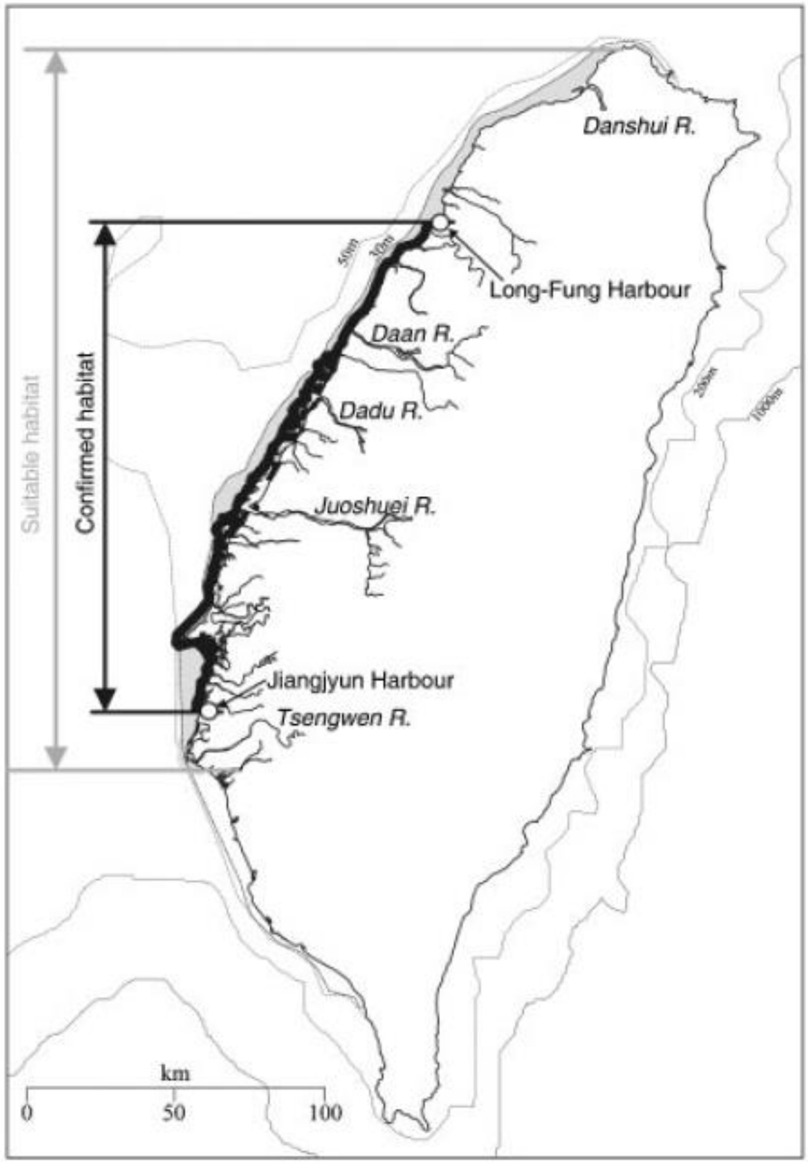

Figure 1: The shallow (< 30 m), nearshore (< 3 nm) coastal waters of western Taiwan are home to an isolated population of dolphin, the 'Taiwanese White Dolphin' (*Sousa chinensis*). The area is also heavily impacted by habitat destruction, noise, air and water pollution, freshwater diversions from major estuaries and fisheries interactions. Workshop participants recommended implementing mitigative measures in the full range of TWD habitat, depicted here as 'confirmed habitat' plus adjacent 'suitable habitat' so as to avoid edge effects (from Ross et al. 2010).

Threats related to fisheries have previously been the focus of an expert TWD workshop. A workshop held in Taipei in April 2011 itemized the direct (mortality and injury) and indirect (depletion of prey through fishing practices) threats to the TWD (Slooten et al. 2013). That study estimated that 6,318 fishing vessels were operating inside the dolphins' habitat, corresponding to 32 vessels per km of coastline. While data on fatal interactions with fisheries is lacking, a photo-identification catalogue has revealed that many individuals bear scars and disfigurements from likely interactions with fishing nets, lines or vessels (Figure 2). The authors concluded that a single fisheries-related mortality every seven years or less would not be sustainable for the population.

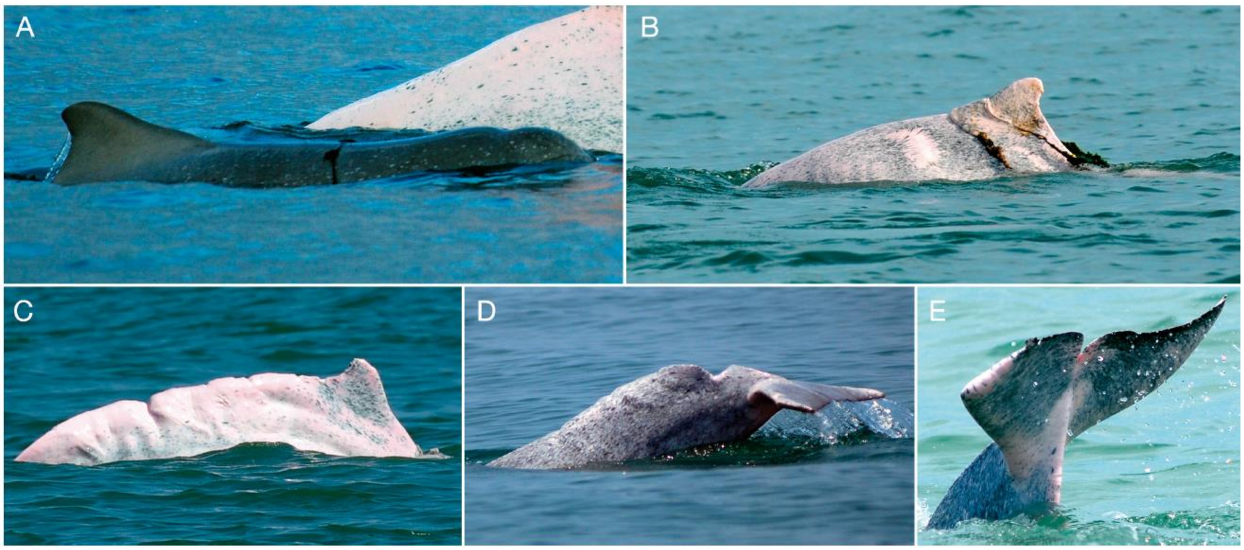

Figure 2: Taiwanese White Dolphins entangled in fishing gear (A and B) or bearing injuries caused by fishing gear (C, D and E). In all cases, the injuries are suspected to be from monofilament nets, likely gill nets or trammel nets. Photographs by John Y. Wang (FormosaCetus Research Group); Figure from Slooten et al. 2013.

Objectives of the 2014 workshop

This report presents a summary of findings from a second fisheries-related workshop held in April 2014 ('Sustainable Fisheries and the Conservation of the Critically Endangered Taiwanese white dolphin, *Sousa chinensis'*). This workshop built on the findings of Slooten et al. (2013) and proposes solutions to the fisheries threat.

The objectives of this workshop were to:

- Evaluate the current status of the TWD population based on the latest data;
- Produce a list of recommendations derived from a risk-based ranking of possible solutions to the fisheries threats;
- Document educational and outreach activities that would generate support for protection measures;

- Provide international examples to illustrate the positive ecological and economic benefits that arise when area-based protection measures are implemented.

Current status of Taiwanese white dolphins

To provide a current assessment of population status, we undertook three separate quantitative analyses. First, we conducted demographic analysis (following Currey et al. 2011) of annual sightings compiled from a photo-ID dataset collected between 2002 and 2013 (Wang et al. 2012; Wang, unpublished data). We applied temporal symmetry capture-recapture analysis (Pradel 1996), implemented in Program Mark (White and Burnham 1999), to estimate apparent adult survival and population growth rates. We considered time-variant and time-invariant models in our model selection (Burnham and Anderson 2002), assessed model fit via bootstrap simulation and estimated c-hat to correct for overdispersion.

The most parsimonious demographic models had time-invariant adult survival and population growth rates with time-variant recapture probability (Supplementary Table S1). Adult survival was 0.9462 (SE = 0.0186; 95%CI: 0.8956-0.9730) while population growth rate was 0.9755 (SE = 0.0273; 95%CI: 0.8084-0.9974). Recapture probability increased over the study period from a low of 0.2427 in 2004 to a high of 0.9323 in 2011. The estimate of adult survival was lower and more precise than the previous point estimate (Wang et al. 2012). The estimated population growth rate implies the population is currently declining at ~2.5% per annum. While there is uncertainty around the rate of decline, the likelihood that the population is declining is more certain (at least 97.5% certain) as the upper 95% confidence limit of the estimate of population growth rate did not exceed 1.

The second approach was an update of a previous population viability analysis (PVA) of the Taiwanese white dolphin (Araújo et al. 2014) with new data from 2011 to 2013. The original analysis aimed to understand the current population status and how different scenarios of realistic additional threats from human activities would affect the dynamics of this highly-endangered population. From this analysis, the population was estimated to have a negative stochastic growth rate of -0.003 (SD = 0.104). The PVA was performed using VORTEX 9.99b, which is a Monte Carlo simulation package designed to model the effects of deterministic factors and demographic, environmental and genetic stochasticity on population dynamics (Lacy et al. 2009). Demographic parameters (e.g., abundance, reproduction rates) used in the model were the same as the previous analysis (see Araújo et al. 2014; Supplementary Table S2), except for the inclusion of the updated estimate of survival rate obtained from the analysis above. From the new simulations the population showed a negative stochastic growth rate of -0.041 (SD = 0.117), which also indicated a marked decline.

The third method aimed to estimate the schochastic growth rate of the Taiwanese white dolphin population by applying a stage-structured matrix population model (Caswell, 2001). When available, population-specific vital rates were used as input parameters for the model (Supplementary Table S3). Otherwise, parameters from other populations or similar species were used instead. Survival estimates of adult and non-calf immature individuals and calving interval were obtained from mark-recapture analysis of Taiwanese white dolphins using photo-identification data from 2002 to 2013. The ratio between calf/adult survival rates observed for bottlenose dolphins along the coast of Florida (Wells & Scott 1990) was used to infer calf survival rate of the Taiwanese white dolphin population based on the estimated adult survival rates. Fecundity of adult females was derived from calving intervals (one female calf produced every ten years per female) and the age at which dolphins attain sexual maturity was assumed to be the same as the provisional population inhabiting coastal waters of Hong Kong (Jefferson et al., 2012). Based on the stage-structured matrix population model, the mean estimated stochastic growth rate of the Taiwanese white dolphin was negative (-0.4%; 95%CI: – 4.3% to +2.9%), indicating a yearly decline.

Despite the differences in model structures and the underlying assumptions, all three models employed suggested that the Taiwanese white dolphin population is declining at similar rates.

Establishing recovery objectives

In the absence of a clear quantitative management objective for the Taiwanese white dolphin, we developed an approach to provide robust, biologically-realistic recovery objectives to guide recovery planning and enable future evaluation of management strategy effectiveness. We propose that the recovery objective for the population be to improve the IUCN red list status of the population over a biologically-achievable timeframe, governed by the current population size (74 animals; Wang et al. 2012) and a biologically-plausible population growth rate to reach the threshold population levels at associated times. In this instance, we estimated the period of time required, given a specified population growth rate, for the population to exceed 50 mature animals, or 100 individuals assuming 50% are mature (Taylor et al. 2007). Reaching 50 mature animals is the population size necessary for an improved IUCN red list status under criterion D (IUCN 2012). For the specified population growth rate, we would recommend applying either a rate of 2%, which equates to half the default maximum population growth rate for small cetaceans (Wade 1998), or the current population growth rate, whichever is higher. These rates of population growth are the maximum that can be expected from a population that is currently declining, allowing time for management to be implemented and the population to respond. Given that the Taiwanese white dolphin population is currently declining, we estimated the time for the population to reach 100 individuals applying a deterministic population growth rate of 2%.

Applying this approach, we recommend the adoption of two specific recovery objectives. The immediate recovery objective would be for the population to increase to at least 100 Taiwanese white dolphins by 2030. This number would mean the population met the criteria for improving the population's IUCN Red List status from 'critically endangered' to 'endangered'. The ultimate recovery objective would be to improve the status of the Taiwanese white dolphin to one whereby the population is no longer listed under any of the threatened categories of the IUCN Red List.

Major Wildlife Habitat designation

The ETSSTAWG welcomes the Taiwanese Forestry Bureau's proposed designation of the Taiwanese white dolphin's Major Wildlife Habitat. This, if enacted as proposed, would provide a tool for mitigation measures. The ETSSTAWG congratulates the Bureau on this important first step towards recovering this critically endangered population.

Because it is critical to protect the dolphins' priority habitat we recommend that, when the opportunity arises, the following revisions to this MWH designation should be made:

1. The northern and southern boundaries of the Major Wildlife Habitat should be extended to the Danshui River Estuary and the Tsengwen Estuary, respectively, to cover both the confirmed habitat and the suitable habitat of the dolphins (as described in Ross et al. 2010).
2. It is critical that the boundaries of the Major Wildlife Habitat (including shorelines) are clearly delineated for effective implementation. We recommend defining the shoreline as the area that is exposed at the lowest low tide of the year, as in Taiwan's Wetland Conservation Act (including sandbars), in order to include all nearshore areas important to the dolphins.
3. The 50 metre buffer between the shore and the proposed (designated) Major Wildlife Habitat should be removed, with the eastern boundary of the habitat being the shoreline (as defined above) as this also constitutes part of the dolphins' priority habitat and provides vital connectivity with freshwater systems that maintain the integrity of the Taiwanese white dolphins' priority habitat.
4. The offshore boundary should be set at 3 nautical miles from the shore (as defined above), throughout the dolphins' priority habitat. This boundary corresponds with the existing nearshore trawling ban, thereby simplifying enforcement of the various regulations which will affect the area.

Benefits from Marine Protected Areas

Concerns about the cumulative impacts of human activities on the diversity and abundance of marine species have led to the establishment of marine protected areas (MPAs) in many parts of the world. MPAs as a management tool can help arrest further degradation of ecosystems and allow them to naturally rehabilitate (Marine Parks Authority 2008).

Marine protected areas have been used successfully in cetacean conservation (Gormley et al. 2012, Hoyt 2011, Clark et al. 2010). Designed and managed properly, MPAs can protect not only the cetaceans themselves but also areas that they use regularly for feeding, socializing, calving, resting or even migrating, with such areas encompassing 'priority' habitats (Ross et al. 2011, Hoyt 2011). Protecting these areas ensures the survival of the cetacean in question, and allows healthy population growth rates (Hoyt 2011). Functional links to other ecosystems that help maintain the integrity of the priority habitat must also be considered when establishing marine protected areas for cetaceans (Ross et al. 2011).

Protecting priority habitats is of greater importance for cetacean species whose distributions are restricted to coastal, estuarine and riverine ecosystems - areas that are highly vulnerable to human impacts (Ross et al. 2011). An ecosystem-based protection strategy, which protects coastal waters and contiguous estuaries, mangroves and riverine ecosystems, will not only give the TWD population the chance to persist and thrive, but will also increase biodiversity, stabilize ecosystems, increase fishery production and improve quality of life for people reliant on the coastal environment.

The declaration of MWH on the western coast of Taiwan for the TWD demonstrates the positive intent on the part of the Forestry Bureau for the future of this critically endangered population. However, this declaration is not an end in itself and needs complementary support from local governments, local residents, and industry to ensure the success of the MWH. One high value action would be the designation of county-based no-take marine protected areas, especially near estuaries, to encourage the recovery of depleted fish stocks. The MWH essentially covers estuarine habitats, and has the potential to increase productivity if further habitat degradation is arrested, pollution is reduced, and fisheries are protected. Such a bottom-up approach has proved highly successful in other areas (Alcala and Russ 2006).

Economic and aesthetic benefits can result from marine protected areas, as has been shown in many parts of the world. Direct benefits can come from the resultant increase in fish biomass and subsequent increase in fishery yields in areas outside the reserve, as well as from revenue from tourism. When managed properly, a thriving, healthy population of cetaceans in a fully protected habitat can have great socio-economic value for the region they inhabit. In addition, dolphins have intrinsic and aesthetic importance or *existence value* (Conservation International 2008), with which people can associate a significant economic value.

<u>Enhanced Fisheries</u>

Many examples exist from around the world wherein no-take fish reserves or protected areas in coral reef, mangrove and estuarine habitats have resulted in increased fish catch through the *spillover* process i.e. when increased production within the reserve results in emigration of target-size fish (Alcala 1988, Alcala and Russ, 1990, Russ and Alcala 1996, Beck et al. 2001, Roberts et al. 2001, Russ et al. 2003, Russ et al. 2004, Alcala et al. 2005, Nam et al. 2005, Sanjurjo et al. 2005, Alcala and Russ 2006, Abesamis et al. 2006, Russ and Alcala 2011). In addition, depending on local hydrodynamic patterns, marine reserves can also export larvae, with some having been detected as far away as 184 km (Christie et al. 2010). Overall, the benefits of no-take MPAs outweigh the costs arising from a decrease in fishable areas (Sanchirico 2000). Direct economic benefits in the form of fishery yields and tourism have varied with different types of protected habitats and different sizes of MPAs, but are clearly depicted from a number of examples (Table 1).

A case study in the Philippines showed that after 16 years of protecting a 22.5 ha no-take marine reserve established by the local (village) government at Apo Island reef, hook-and-line fishery catch per unit effort (CPUE) increased by 50% in areas outside of the reserve (Russ et al. 2004). During this period, fishing effort declined by 46%, suggesting that fishers were able to get more fish with less effort. Fishers did not have to go far from their island, thereby reducing fuel costs. Hook-and-line CPUE for surgeon fishes (Acanthuridae = *Ctenochaetus* spp., *Acanthurus* spp. and *Naso vlamingii*) increased significantly in areas closest (~200 m) to the reserve, whereas that of carangids increased away from the reserve. The pattern of increased abundance within 200-250 m of the reserve was first observed in 1990, eight years after the reserve was established. Visual census of the fish biomass inside the reserve supported the information on the increased CPUE outside the reserve. Biomass of jacks, pompanos (carangids) and surgeon fishes (acanthurids) increased threefold inside the reserve, from approximately 30 kg/1000 m^2 to about 100 kg/1000 m^2**.** The fishery and tourism benefits generated by the reserve have enhanced the living standard of the fishing community. The initial one-time investment of USD 75,000 to set up this reserve yielded an annual return of between USD 31,900 and USD 113,000 in increased fish production and local dive tourism (White et al. 2000).

Fishing gear used by the villagers changed over the period. Drift gillnets, commonly used in 1980/1981 (Alcala and Luchavez 1981), were eliminated after 1999/2000 (Russ et al. 2004).

The protection of mangroves can also result in economic benefits, as shown for Mexcaltitán Island in Mexico. Acting as nurseries for fish and shrimp, the mangroves provided residents with direct fishing benefits of more than USD 1.0 million annually (Sanjurjo et al. 2005).

Estuaries also serve as nursery grounds for fish and invertebrates, exporting larvae and juveniles to seagrass beds, coral reefs, and pelagic and deep sea ecosystems (Beck et al. 2001). The average global value of estuaries is estimated to be around USD 22,832 per ha per year (Coztanza et al. 1997). In the U.S., 75% percent of commercially important fish species inhabit estuaries for part or all of their lives (Oceanservice.noaa.gov). Fish catch from this ecosystem contributes USD 4.3 billion to the U.S. economy each year (Oceanservice.noaa.gov). In South Africa, an estimated USD 267 million in annual income is derived from the fishery, tourism and nursery functions of 149 estuaries (Turpie and Clark 2007). Because of their substantial contribution to the economy and their essential ecological functions, a substantial percentage of these estuaries are protected (Turpie and Clark 2007). Estuarine reserves, like coral reef MPAs, have been shown to supply nearby unprotected areas with large-sized fish and crustaceans through the spillover process (Roberts et al. 2001, Butcher et al. 2002).

Table 1. Examples of economic benefit derived from marine protected areas. Incomes are from fisheries adjacent to the reserves and tourism within and outside the reserves. Annual income is from combined fishery and tourism unless stated otherwise.

LOCATION	HABITAT TYPE	AREA of MPA (ha)	ANNUAL INCOME (USD)	REFERENCE
Apo Island Marine Sanctuary, Philippines	Coral reefs	22.5	31,900 – 113,000	White et al. 2000
Bohol Marine Triangle, Philippines	Coral reefs, seagrasses	160	3.81 M	Samonte-Tan et al. 2007
Mexcaltitán Island, Mexico	Mangroves	-	1 M	Sanjurjo et al. 2005
Mombasa Marine National Park, Kenya	Coral Reefs	21,000	10,200-12,024/100ha (fishing) + 3.5M (tourism)	McClanahan 2010, Hicks et al. 2009
Bonaire Marine Park, Antilles	Coral reefs	-	19 M (tourism)	Pendleton 1995
Wakatobi National Park, Indonesia	Coral reefs	2,545	308,000	Hargreaves-Allen 2004
Hon Mun Marine Protected Area, Vietnam	Coral reefs	13,000	2M (fishery), 4.2M (tourism)	Nam et al. 2005
Cape Floristic Region, South Africa	149 Estuaries	-	267 M	Turpie & Clark 2007
Northern Australia (Northern Prawn Fishery)	Seagrass beds (prawn habitat)	1.6 M	162.8 M	Commonwealth of Australia 2003 (http://www.environment.gov.au/)
Great Barrier Reef Marine Park, Australia	Coral reefs	34.4 M	5.5 B (tourism)	McCook et al. 2010

Whale and Dolphin Watching

Whale and dolphin watching has become popular in recent years, and marine protected areas that highlight cetaceans have increased their economic drawing power for local communities (Hoyt 2011). MPAs that feature cetaceans, especially rare and endangered species, have an added attraction and provide a good opportunity for educating the public about conservation. Sustainable tourism is an important component of conserving marine ecosystems, and marine protected areas provide a 'powerful, convincing method of marketing and protecting the marine environment' (Hoyt 2011). Whale and dolphin watching, as well as other components of tourism, must remain sustainable and conducted within the overall conservation goals of the MPA. For coastal and estuarine species and populations that are in peril, land-based observations may be the preferred way to sustain tourism opportunities. Whale and dolphin watching is one of the fastest growing tourism industries in the world, bringing in revenue of USD 2.1 billion per year (O'Connor et al. 2009). Some examples of revenue derived from dolphin and whale watching activities are shown in Table 2.

The majority of wildlife species and/or populations are not managed as commodities or resources and do not have a marketplace value. Due to this lack of perceived commercial worth, it can be difficult to express the value that human populations place on the aesthetic and ethical importance of such animals. In the case of marine mammals, it has been well documented that the majority of people value the existence of these animals and would regret a loss or decline in population size and/or habitat quality (Hageman 1985, Loomis & Larson 1994, Wallmo 2006, Rudd 2007, Ressurreicao et al. 2012, Boxall et al. 2012, Hung et al. 2014). This 'non-use' value is often higher for charismatic marine mammal species when compared to terrestrial animals and other aquatic animals (White et al. 2001, Rudd 2007, Ressurreicao et al. 2012). Endangered and threatened species are also valued much higher than those animals not at risk (White et al. 2001, Syneca Consulting 2009).

Table 2. Examples of annual income from whale and dolphin watching activities.

LOCATION	SPECIES	ANNUAL TOURISM EXPENDITURES (USD)	REFERENCE
Cambodia & Laos	Irrawaddy dolphin	4.2 M	O'Connor et al. 2009
Hong Kong	Humpback dolphin	225,000	Yeung et al. 2015
Canary Islands	Sperm whales + small cetaceans	56.5 M (2008)	O'Connor et al. 2009
Samadai Reef, Egypt (dolphin MPA)	Spinner dolphin (main species)	500,000	O'Connor et al. 2009
Australia	Large and small cetaceans	171.9 M	O'Connor et a. 2009
Maldives	Large (Blue, Bryde's Sperm whales) and small cetaceans	581,536 (2008)	O'Connor et al. 2009
Malaysia (Kuching & Langkawi)	Main species: Irrawaddy dolphin	460,250 (2008)	O'Connor et al. 2009
Philippines	Large & small cetaceans	1.62 M (2008)	O'Connor et al. 2009
Mayotte	Humpback whales	1.6 M (2008)	O'Connor et al. 2009
Myanmar (Burma)	Irrawaddy dolphin	6,760 (2008)	O'Connor et al. 2009
Nepal	Ganges River dolphin	4,323 (2008)	O'Connor et al. 2009
Taiwan (Yilan, Hualien, Taitung)	Small cetaceans	16.2M (2008)	O'Connor et al. 2009
Tonga	Large and small cetaceans	700,000	Orams 2002
Dominica	Dolphins(~7 spp), whales (mainly sperm whales)	383,000- 970,000	http://www.mygrenada.org/info.htm/whale_dominica.htm
Japan	Dolphins, whales	33 M	Hoyt 2001

In order to assess the 'non-use' value of wildlife species/populations, the contingent valuation method can be used. This technique uses surveys to measure the public's direct willingness to pay for the continued prosperity of a target species/population (Hanemann 1999; Carson et al. 2003). Substantial values have been associated with the existence of marine mammals and reflect the great economic importance of protecting these animals for future generations. Published reports indicate these values can be as high as 12.1 billion USD per year, and perhaps more depending on the scenario (Redden 2008; Table 3). Just as important is the public's willingness to accept a loss in order to prevent reductions in population size or habitat quantity/quality (Syneca Consulting 2009, Hung et al. 2014). This was demonstrated for Indo-Pacific humpback dolphins in Hong Kong waters where residents were willing to spend, on average, an extra 21.2 minutes on the commuter ferry to avoid going directly through dolphin habitat. Based on the human population size and the median hourly wage in Hong Kong, the indirect willingness to pay was valued at 2.67 billion HKD (344 million USD) over the next ten years. Based on the results of willingness-to-pay surveys for other marine mammals, we suggest that the people of Taiwan, as well as the international community, will hold very similar feelings towards the Taiwanese white dolphins and that the protection and recovery of this population is of substantial value.

Table 3: Review of non-consumptive value studies for marine mammals generated using the contingent valuation method. Published values have been corrected to reflect the current value using inflation rates. Total value was compared between studies by calculating the total willingness to pay in USD for the entire study population.

Species	Location	Willingness to Pay (WTP)			Commitment Length	Human Population size	Goal	Reference
		Published Value	Corrected for Inflation (2014)	$US/human population				
Indo-Pacific humpback dolphins	Hong Kong	1.589 billion HKD/ year (2014)	-	2.05 billion USD	Annually for 10 years	2013: 7,219,700 (Census and Statistics Department)	Protect existing humpback dolphin habitat in Hong Kong	Hung et al. 2014
Bottlenose dolphins	California, USA	17.73 USD/ person (1984)	40.32 USD/ person	1.5 billion USD	Annual	2013: 38,332,521 (US Census Bureau)	Prevent loss	Hageman 1985
Killer whales	USA	111.76 USD/ person (2006)	130.89 USD/ person	12.1 billion USD	Annual	2006: 92,548,000 tax returns filed with owing taxes	Protection against loss	Redden 2008
North Atlantic right whales	Canada	22.92 CAD / person(2006)	25.75 CAD/ person	836.97 million USD	Annual	2014: 35,344,962 (Statistics Canada)	Increase population 25-100%	Rudd 2007
Baleen whales	Canada	81 CAD/ person (2009)	88.67 CAD/ person	1.97 billion USD	Annually for 5 years	2014: 35,344,962 (Stats Canada)	Reduce fisheries entanglement	Lyssenko & Martinez-Espineira - 2009
California sea otters	California, USA	20.75 USD/ person (1984)	47.19 USD/ person	1.8 billion USD	Annual	2013: 38,332,521 (US Census Bureau)	Prevent extinction	Hageman 1985
Northern elephant seals	California, USA	18.29 USD/ person (1984)	41.60 USD/ person	1.59 billion USD	Annual	2013: 38,332,521 (US Census Bureau)	Prevent loss	Hageman 1985
Marine mammals in St. Lawrence Estuary	Canada	77-229 CAD/ household (2006)	88.49-263.16 CAD/ household	3.23 billion USD	Annual	2011: 13,319,250 households	Marine mammal recovery	Boxall et al. 2012

Measures to reduce fisheries impacts on dolphins

We reviewed numerous mitigation measures that could be used to reduce fisheries impacts to the TWD. Possible solutions outlined by workshop participants were defined and rated in terms of likely effectiveness in the following three qualitative categories (Table 4):

- *Ineffective (red)*: Proposed solutions deemed ineffective or inappropriate by the expert group included pingers and Vessel Monitoring Systems (VMS; this should be viewed not as a mitigation option, but rather a potentially valuable enforcement tool);
- *Moderately effective (yellow)*: Proposed solutions deemed moderately effective, included the removal of fuel subsidies, creation of a gillnet exclusion zone, voluntary buy-out of gillnet and trammel net fishers, and a 3-year phase out of gillnets and trammel nets;
- *Effective (green)*: Proposed solutions deemed high effective included gillnet and trammel net ban, compulsory buy-outs, and shifts to alternative fishing gear.

Based on our extensive review of international mitigation measures, the three measures highlighted in green (Table 3) offer the greatest likelihood of eliminating fishing bycatch of TWD. To meet our management target of improving TW conservation status through downlisting, we recommend combining these mitigation measures into one comprehensive approach to eliminate the use of trammel nets, gillnets, and trawling throughout TWD habitat.

The approach would require:

- The banning of all gill and trammel nets within TWD habitat;
- A buyout of or subsidy for all fishermen willing to engage in an alternative livelihood; and
- A subsidy for all other fishermen to switch to hand gear.

While decision makers and fishers may prefer to phase these actions in over time, doing so will reduce the effectiveness of these measures. For that reason, we recommend that any ban be coupled with an aggressive enforcement strategy, buyout and gear conversion program, making it potentially more acceptable to affected fishers. Implementation of this recommendation will recover overfished fish stocks, promote species biodiversity, contribute to TWD recovery, and improve the quality of life of human residents.

Table 4: Mitigation measures for Taiwanese white dolphin (TWD) recovery within Priority Habitat. Candidate measures were assessed and ranked in terms of their likely effectiveness in reducing fisheries impacts to the TWD as 'ineffective' (red), 'moderately effective' (yellow), and 'effective' (green). [1]Potential Biological Removal; [2]Time to implement is defined here as: Short (<1 yr), Medium (1-3 yrs), Long-term (>3 yrs): does not consider political will, just ease of implementation.

Candidate solutions for TWD Recovery	Benefit to Habitat and Fish Stock Recovery	Level of Probable Risk Reduction	Acceptance by Fishermen	Ease of Implementation and Enforceability	Economic Costs to Implement	Likelihood of Success (Reaching PBR[1])	Time to Implement[2]
No Action (Status Quo)	None	None	High	High	None	None	None
Pingers	None	None	Low	Low	Medium to High	None	Long
Reflective and stiffnets	None	None	Low	Low	Medium to High	None	Long
Enforce Trawl Exclusion	High	Medium	Low (trawlers) High (non-trawlers)	High (esp. with VMS)	Medium (if VMS required)	Low	Short
Remove all subsidies (for fuel and 90 days fished)	High	Low	Low	High/None	None	None	Short
Create a gillnet exclusion zone (move gillnets out of TWD habitat)	High	High	Low	Low/Medium	Low (if no compensation)	High	Medium

Candidate solutions for TWD Recovery	Benefit to Habitat and Fish Stock Recovery	Level of Probable Risk Reduction	Acceptance by Fishermen	Ease of Implementation and Enforceability	Economic Costs to Implement	Likelihood of Success (Reaching PBR[1])	Time to Implement[2]
Buy-out Gillnet and Trammel net Fishers (voluntary)	Low to Medium	Low	Low to Medium	Low/Low	High (high to gov't, low to fishers)	Low	Medium-Long
3-yr Phase out of Gillnets and Trammel net	High	Medium	Low	Low/High	Medium (to gov't and high to fishers)	High	Medium-Long
Switch to Handlines	High	High	Low	High (because Coast Guard can monitor outgoing vessels)	High (for gov't and fishers)	High (negating other threats)	Medium to Long
Immediate Ban on Gillnets and Trammel	High	High	None	Low/High (because could shift to gillnet & Coast Guard cannot differentiate)	High (low for gov't and high for fishers)	High (negating other threats)	Medium to Long
Buy-out Gillnet and Trammel net Fishers (mandatory with ban above)	High	High	Medium to High	Low/High	High (high to gov't, low to fishers)	High	Medium-Long

Of the recommendations in yellow that offer marginal bycatch reduction, we recommend that Taiwan enforce the current trawler exclusion zone and remove all subsidies that encourage overfishing such as subsidies for fuel or that require a minimum number of fishing days.

Communication and education

The importance of raising awareness among government agencies, fishers and other local stakeholders for achieving marine conservation and management goals is widely recognised and documented (e.g. Grorund-Colvert et al. 2010; Himes 2003; Johannes 2002; Marques et al. 2013; Wever et al. 2012; White 1989). Effective communication of marine science is not only essential for establishing appropriate management plans for marine areas, but also for ensuring compliance, and for mitigating potential conflicts between users with diverse needs and opinions (Grorund-Colvert et al. 2010).

The successful implementation and enforcement of the policy recommendations outlined in this paper will depend to a large extent upon there being high levels of awareness and support among people currently regulating, managing and extracting marine resources from the waters in and around the critical habitat of the Taiwanese white dolphin population. Both short and long term educational and communication measures could stimulate concern, dialogue and action among a variety of audiences in Taiwan. However, the immediacy of fisheries threats to the dolphin population dictates that targeted action to quickly increase awareness and knowledge amongst those most directly involved in and able to influence the activities leading to fisheries impacts (i.e. fishers, policy makers and law enforcers) must be prioritised.

An increasing international focus on co-management for fisheries, wherein government bodies and communities work together towards agreed goals, attests to the growing recognition that awareness and active participation among local fishing communities can be vital to the success of marine conservation efforts. Gutiérrez et al. (2011) suggest that co-management offers “the only realistic solution for the majority of the world’s fisheries”. Benefits include greater compliance with fisheries regulations by local users, as well as increased management capacity through the participation of local partners (Levine and Richmond, 2014).

A well-known case of successful marine resource co-management is the no-take zone established near Apo Island, Philippines in 1982 (Alcala and Russ 2006). In this case, significant effort was placed on educating the local fishermen and residents of Apo Island about the environment and marine resource protection. The high degree of organization, planning and education undertaken, beginning in the mid-1970s, was crucial in empowering local people to protect marine resources in their waters (White 1989). Education in combination with legislation created a successful community-based coastal resource management program which quickly spread to neighbouring communities (Alcala and Russ 2006).

Awareness within relevant government agencies is equally critical. A variety of national and subnational government agencies in Taiwan administer policies affecting the Taiwanese white dolphins and their habitat. Therefore the success of conservation measures hinge greatly upon their collective understanding of the situation and their endorsement of mitigation measures.

The importance of official support was highlighted by Levine and Richmond (2014) in a comparison of fisheries co-management programs in Hawai'i and American Samoa. Support from the government in American Samoa contributed to the creation of functioning programs by enabling the design and implementation of necessary legislation. The agency also provided training and workshops for the local communities, which increased local knowledge and capacity to manage marine resources, and was responsive in the face of problems that arose. This helped keep the program adaptive - an important factor in its success. In contrast, a lack of buy-in from the government partner in Hawai'i "severely impeded program implementation".

Meanwhile, raising awareness amongst the wider public could ensure that resources are made available and action is taken to address the threats to the Taiwanese white dolphins. Martín-López et al. (2009) found that public preference for certain species led to a greater allocation of funds for their conservation. Building greater awareness and understanding is also important for developing citizens' sense of personal responsibility for marine conservation, which can in turn support national marine policy objectives (McKinley and Fletcher 2012). Poor awareness of personal roles and responsibilities can, on the other hand, lead to a lack of mobilisation among stakeholders (Wever et al. 2012).

In the longer term, children in Taiwan represent the next generation of fishermen and politicians, so it is also important to educate, engage and inspire them as early as possible. Educational programs are often aimed at school-aged children as they are generally more receptive and sensitive to environmental education (van Bressem et al. 2006). In Peru, educational programs were introduced with measureable success to school-aged children to complement the legislative measures protecting cetaceans and other marine animals (van Bressem et al. 2006).

The educational and communications needs of different stakeholders can vary greatly and need to be carefully considered when developing educational strategies, tools and materials. Grorund-Colvert et al. (2010) developed comprehensive communications materials to increase understanding of marine reserve science among a range of audiences, but found that, despite the broad success of their efforts, their materials did not provide all the information desired by fishermen – a key stakeholder group. Elsewhere, highly tailored solutions have been developed which are worth exploring, such as REEFGAME, a computer-assisted role-play game which enables fishers to understand how their activities and choices can affect the marine environment (Cleland et al. 2012).

Where such diverse audiences are to be engaged, it can be helpful to adopt time-tested principles from the fields of communications and education. Grorund-Colvert et al. (2010) propose four steps to developing an effective strategy for communicating about marine reserve science, based on such principles. These are: 1) know the audience; 2) identify the main messages; 3) choose the communication tactics; and 4) measure success. For developing key messages, they suggested four areas to highlight: 1) the problem (such as changes to ocean ecosystems); 2) why the problem matters to the audience; 3) potential solutions; and 4) what benefits could result from the solutions.

In the context of more formal education, Brewer (2002) identified five elements that are common when developing conservation education programs, specific to endangered species, to engage nonscientific audiences. These elements include: 1) developing ecological literacy by having students share their knowledge; 2) collaboration between scientists and educators; 3) guidance for scientists on the best approaches for translating information and engaging students across knowledge levels; 4) proper training for participants on data collection during research partnership activities; and 5) program evaluations.

Grorund-Colvert et al. (2010), Brewer (2002) and others (e.g. Jacobson, 1991) emphasize the importance of evaluation processes and feedback for assessing and improving educational programs and communications strategies. Given the urgent need for mitigation of the threats to the Taiwanese white dolphins, any educational programs that are introduced should be regularly evaluated to ensure that they help achieve real impact within a relevant time-frame.

Workshop recommendations

In summary, the workshop recommended the following:

- The immediate banning of all gill and trammel nets within TWD habitat (see Ross et al. 2010 for boundaries);
- Compensation for fishers willing to engage in alternative livelihoods;
- Compensation to aid in the transition to alternative fishing gear that is both sustainable and dolphin-friendly, such as handlines; and
- A strict enforcement of the existing inshore (<3 nm) trawler ban.

Each of these solutions must be implemented immediately and in concert; otherwise dolphins will continue to suffer from life-threatening injuries and stress, and occasionally die. Such impacts will jeopardize recovery and/or contribute to the extinction of this population. The government of Taiwan's recent designation of 'Major Wildlife Habitat' (MWH; akin to 'Critical Habitat' elsewhere) will provide opportunities for government managers to implement protection measures related to fishing and other threats. As the MWH proposed by the government of Taiwan is smaller than the previously described 'confirmed habitat' for the TWD, it will be important to implement the workshop recommendations well beyond the proposed MWH boundaries so as to avoid edge effects, which can increase the risk of extinction (Woodroffe and Ginsberg 1998). We therefore recommend that these measures be implemented throughout the previously recommended TWD 'priority habitat' which comprises both 'confirmed habitat' and adjacent 'suitable habitat' (Ross et al. 2010).

Programs to encourage the establishment of local, county-based, no-take zones or marine protected areas (especially near estuaries) were also recommended by workshop participants to complement the actions of the national government and help recover severely depleted coastal fish stocks. In the absence of a clear, quantitative management objective for the TWD, the workshop recommended the adoption of two recovery objectives. The immediate recovery objective would be for the population to increase to at least 100 individuals by 2030, which would also mean improving the population's IUCN Red List status from *Critically Endangered* to *Endangered*. The second (ultimate) recovery objective would be to improve the population's status such that the population is no longer listed under any of the threatened categories of the IUCN Red List of Threatened Species.

If implemented, this plan will:

- Eliminate the threat of entanglement, injury and death associated with trawling, gill and trammel nets within 3 nm of shore in TWD habitat;
- Lead to a recovery of fish stocks along the west coast of Taiwan, which appear to have collapsed (monitoring of fish stocks will be essential to developing fisheries recovery targets);
- Provide medium- and long-term economic benefit for fishers and their families;
- Contribute to sustainable ocean resources for future generations of people and wildlife;
- Create economic opportunities in the sustainable ecotourism sector.

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Supplementary Information

Supplementary Table S1. Model ranking of temporal symmetry capture recapture models estimating apparent annual survival (Phi), population growth rate (Lambda), and recapture probability (p) for Taiwanese white dolphins. Shown are the Akaike's information criteria corrected for overdispersion (QAICc; c-hat = 3.888), the delta QAICc, the AICc weights, the number of parameters, and the deviance for each model. A (.) denotes an invariant parameter, while (t) denotes a time-variant parameter with parameter estimates for each year.

Model	QAICc	Delta QAICc	AICc Weights	Model Likelihood	Num. Par	QDeviance
Phi(.) p(t) Lambda(.)	259.3456	0	0.98693	1	12	62.3952
Phi(t) p(t) Lambda(.)	268.1187	8.7731	0.01228	0.0124	20	53.964
Phi(.) p(.) Lambda(.)	273.6661	14.3205	0.00077	0.0008	3	95.3554
Phi(t) p(.) Lambda(.)	280.9889	21.6433	0.00002	0	11	86.1463

Supplementary Table S2. Summary of demographic parameters used as input data in the modelling of the viability of the Taiwanese white dolphin.

Parameter	Value[1]	Reference
Mating system	Polygynous	T.A. Jefferson, personal comm.
Sex ratio at birth (% males)	50	T.A. Jefferson, personal comm.
First age of reproduction (females/ males)	10/13 years	Jefferson et al., 2012
Maximum age of reproduction	35 years	Based on Jefferson et al., 2012 (see Araújo et al. 2014)
Maximum n. of broods/year	1	Jefferson & Karczmarski 2001
Maximum n. of progeny brood/year	1	Jefferson and Karczmarski 2001
Carrying capacity (K)	250	See Araújo et al. 2014
% Adult females breeding	10 (1 SD)	J.Y. Wang, unpublished data
Mortality rate (%)	5.4 (0.159 SD)	See demographic analysis above
Initial population size	74	Wang et al., 2012

[1] Standard deviation due to environmental variation is shown in brackets.

Supplementary Table S3. Input parameters used to estimate growth rate of the Taiwanese white dolphin. The table includes parameters estimation, their variation, the level of uncertainty (represented by the distribution) and the source. AFR = Age at first reproduction (i.e. age at attainment of sexual maturity plus gestation length). The probability of moving from juveniles (i.e. non-calf immatures) to adults is obtained by iteration – see Caswell, 2001: p. 164).

Parameters/ variables	Estimate	Variation	Chosen distribution	Reference
AFR (years)	10	Min=9; Max=11	Normal	Jefferson et al. 2012
Fecundity	0.10	Min=0.04; Max=0.16	Uniform	based on Jefferson et al 2012
Calf survival	0.7948	SE=0.0186	Beta	Present study and Wells & Scott, 1990
Juvenile survival (P2)*	0.9462	SE=0.0186	Beta	Present study
Adult survival (P3)*	0.9462	SE=0.0186	Beta	Present study

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