Status Review Report of the Taiwanese Humpback Dolphin

Sousa chinensis taiwanensis

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Table of Contents

INTRODUCTION 4
Scope and Intent of the Present Document 4
Taxonomy and Distinctive Characteristics 4
Life History and Ecology 7
Range, Distribution, and Habitat Use 7
Feeding and Diet 9
Reproduction and Growth 10
Social Behavior 11
Population Abundance and Trends 12
ANALYSIS OF THE ESA SECTION 4(a)(1) FACTORS 14
Destruction, modification, or curtailment of habitat or range 14
Overutilization for commercial, recreational, scientific, or educational purposes 23
Disease or Predation 23
Inadequacy of Existing Regulatory Mechanisms 24
Other natural or human factors affecting continued existence 26
ASSESSMENT OF EXTINCTION RISK 29
Demographic Risk Assessment 31
Threats Assessment 33
Overall Extinction Risk 35
CONSERVATION EFFORTS 36

INTRODUCTION

Scope and Intent of the Present Document

On March 9, 2016, the National Marine Fisheries Service (NMFS) received a petition to list the Taiwanese humpback dolphin (*Sousa chinensis taiwanensis*), a subspecies of the Indo-Pacific humpback dolphin (*Sousa chinensis*), as either threatened or endangered under the U.S. Endangered Species Act (ESA). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). NMFS determined the petition presented substantial information for consideration and that a status review was warranted for the subspecies (see following link for the Federal Register notices for the Taiwanese humpback dolphin: https://federalregister.gov/a/2016-11014). Thus, this document is a status review of the Taiwanese humpback dolphin. The ESA stipulates that listing determinations should be based on the best scientific and commercial information available. NMFS appointed an employee in the Office of Protected Resources Endangered Species Conservation Division to undertake the scientific review of the biology, population status and trends, threats, and future outlook for the species. Using this scientific review, NMFS then conducted an extinction risk analysis for the Taiwanese humpback dolphin.

This document reports the scientific review as well as conclusions regarding the biological status of the Taiwanese humpback dolphin. The conclusions in this status review are subject to revision should important new information arise in the future. Where available, we provide literature citations to review articles that provide even more extensive citations for each topic. Data and information were reviewed through February 2017.

Taxonomy and Distinctive Characteristics

Sousa chinensis is a broadly distributed species within the genus *Sousa*, family Delphinidae, and order Cetartiodactyla. The taxonomy of the genus is unresolved and has historically been based on morphology. Current taxonomy defines *Sousa chinensis* as one of four species within the genus, with one identified subspecies (Mendez *et al.,* 2013; Jefferson and Rosenbaum 2014). Each species is associated with a unique geographic range: *Sousa teuzii* (eastern Atlantic), *Sousa plumbea* (Indian Ocean), and *Sousa chinensis* (Indo-Pacific) (Rice 1998); and *Sousa sahulensis* (a newly described species off of northern Australia (Mendez *et al.,* 2013; Jefferson and Rosenbaum 2014)), with recent confirmation of the species off the island of New Guinea (Jefferson, pers. comm. 2017). Although subspecies and population structure for species within the *Sousa* genus remain unresolved, growing genetic and phylogeographic evidence suggests that species within the genus, including *Sousa chinensis,* may be associated with further genetic subdivisions (Frère *et al.,* 2008; Frère *et al.,* 2011; Mendez *et al.,* 2013).

The subspecies of *Sousa chinensis* occurring in the eastern Taiwan Strait (herein referred to as the Taiwanese humpback dolphin – *Sousa chinensis taiwanensis*) was first described in 2002 during an exploratory survey of coastal waters off of western Taiwan (Wang *et al.,* 2004b). However, it was not until recently that the subspecies received formal description (Wang *et al.,* 2015) and recognition (Committee on Taxonomy 2016). Prior to coastal surveys, there were few records mentioning the species in this region, save two strandings, a few photographs, and anecdotal reports (Wang *et al.,* 2004a). Since the first survey in 2002, researchers have confirmed their year-round presence in the eastern Taiwan Strait (Wang and Yang 2011). When young, humpback dolphins appear dark grey with no or few light-colored spots, and transform to mostly white (appearing pinkish) as dark spots decrease with age. However, the developmental transformation of pigmentation differs between Taiwanese and Chinese humpback dolphin populations, and the spotting intensity on the dorsal fin of the Taiwanese population is significantly greater than that in other nearby populations in the Pearl River or Jiulong River estuaries (PRE and JRE, respectively) of the Chinese mainland (Wang *et al.,* 2008). Evidence supporting unique pigmentation in the Taiwanese population was based on 229 individually-recognizable dolphins obtained from two mainland Chinese populations (the JRE and PRE) and from the Taiwanese population (Wang *et al*., 2008). Based on this study, substantially greater spotting intensity on the dorsal fin of the Taiwanese population is consistent, regardless of general age class (Wang *et al*., 2008). Unlike older individuals of other humpback dolphin populations, the Taiwanese humpback dolphins never lose the dark dorsal fin spots completely (Wang *et al*., 2008). In contrast, dorsal fins of Chinese populations are strikingly devoid of spots compared to their bodies throughout most of their lives, except when they are very young or very old (Wang *et al*., 2008). Wang *et al*. (2008) concluded that these differences in pigmentation can be used to reliably distinguish the Taiwanese humpback dolphin from other nearby populations (Wang *et al*. 2008). However, while the 2008 study showed that the pigmentation of the Taiwanese humpback dolphin is significantly different from that of other populations within the taxon, the study did not examine or quantify the degree of differentiation for purposes of determining whether the population warranted subspecies recognition (Wang *et al*., 2015).

Wang *et al*. (2015) expanded upon the previous study (Wang *et al.,* 2008) regarding the pigmentation differences between the Taiwanese humpback dolphin and Indo-Pacific humpback dolphin populations inhabiting the Jiulong River and Pearl River estuaries. Wang *et al*. (2015) compared spotting densities on the bodies and dorsal fins of these neighboring populations and performed a discriminant analysis (Figure 1).

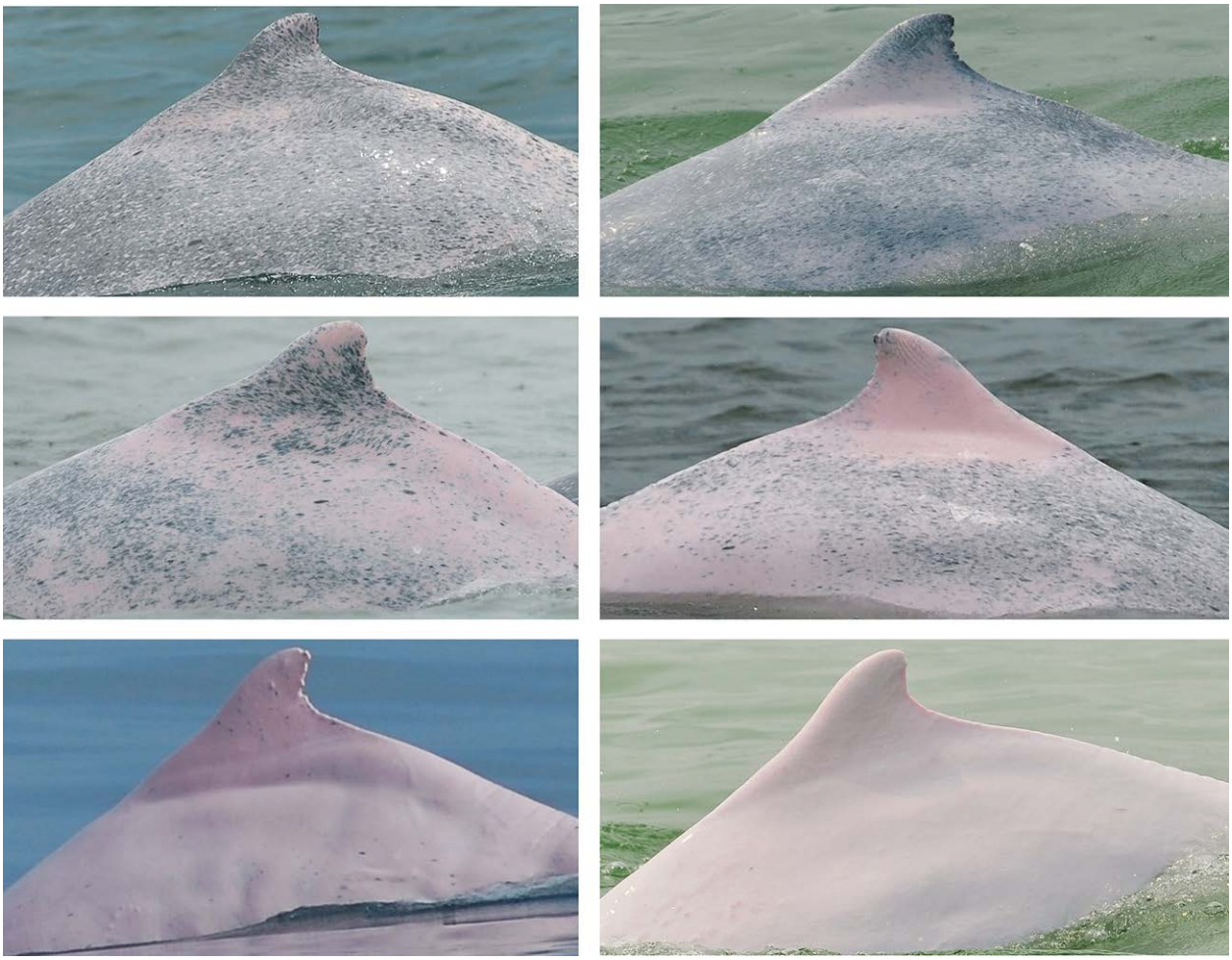

Figure 1 Typical pigmentation patterns of different color classes of Indo-Pacific humpback dolphins from the Taiwanese subspecies (left column) and the putative Pearl River Estuary population (right column). Presumed younger to older individuals are shown from top to bottom. Photographs by John Y. Wang/*FormosaCetus* Research and Conservation Group (from Wang *et al*. 2016).

The analysis of the degree of pigmentation variation patterns between the dolphins from Taiwanese waters and those from the nearest known populations (Jiulong River and Pearl River estuaries of mainland China) revealed virtually non-overlapping distributions (Wang *et al.* 2015). The study stated that the Taiwanese dolphins were "clearly diagnosable from those of mainland China under the most commonly accepted 75% rule for subspecies delimitation, with 94% of one group being separable from 99% of the other" (Wang *et al*. 2015). Based on this information, as well as supporting evidence of geographical isolation and behavioral differences, the authors concluded that the Taiwanese humpback dolphin qualifies as a subspecies, and revised the taxonomy of *Sousa chinensis* to include two subspecies: the Taiwanese humpback dolphin (*S. chinensis taiwanensis*) and the nominotypical Chinese humpback dolphin (*S. chinensis chinensis*) (Wang *et al*., 2015).

While pigmentation of the Taiwanese population is significantly different from other populations within the taxon (Wang *et al*., 2008; Wang *et al*., 2015), whether the pattern is adaptive or has genetic underpinnings is still uncertain. The differences in Taiwanese humpback

dolphin pigmentation may be a result of a genetic bottleneck from the small size of this population (less than 100 individuals) and it is possible that the Taiwanese humpback dolphin represents a single social group (Dungan 2011; Dungan *et al*., 2016). However, Wang *et al*. (2015) concluded: "the differences between the Taiwanese dolphins and their nearest neighbors are not clinal, but are diagnosably different" and the characters examined are likely the result of genetic and developmental differences within the population, as opposed to those that may be environmentally induced. Additionally, several other lines of evidence taken together, including morphological differences, the subspecies' geographical isolation, and general biology of the genus, provide strong support regarding the lack of contemporary exchange of humpback dolphins across the Taiwan Strait (Wang *et al*., 2016; Wang *et al*., 2015). Because of the new information as presented in Wang *et al*. (2015), the Taxonomy Committee of the Society for Marine Mammalogy officially revised its list of marine mammal taxonomy to recognize the Taiwanese humpback dolphin as a subspecies (Committee on Taxonomy 2016).

In terms of distinctive physical characteristics, the Indo-Pacific humpback dolphin is generally easy to distinguish from other dolphin species in its range, as it is characterized by a robust body, long distinct beak, short dorsal fin atop a wide dorsal hump, and round-tipped broad flippers and flukes (Jefferson and Karczmarski 2001). The Indo-Pacific humpback dolphin is medium-sized, up to 2.8 m in length, weighing 250-280 kg (Ross *et al.,* 1994). The Indo-Pacific humpback dolphin has a short dorsal fin with a wide base. The base of the fin measures 5-10% of the body length, and slopes gradually into the surface of the body; this differs from humpback dolphins from the western portion of their range, which have a larger hump that comprises about 30% of body width, and forms the base of an even smaller dorsal fin (Ross *et al.,* 1994). Males and females from the PRE population, and in other populations of Southeast Asia, do not exhibit sexual dimorphism in size, growth patterns, or morphology. In contrast, individuals from South Africa exhibit extensive sexual dimorphism in terms of size and dorsal hump morphology (Ross *et al.,* 1994; Karczmarski *et al.,* 1997; Jefferson *et al.,* 2012)

Life History and Ecology

Range, Distribution, and Habitat Use

The Taiwanese humpback dolphin has a very restricted range; the subspecies resides in the shallow coastal waters of central western Taiwan throughout the year (Wang *et al*., 2007a; Wang *et al*., 2016), with no evidence of seasonal movements (Wang and Yang 2011; Wang *et al.,* 2016). Although the total distribution of the dolphin covers approximately 750 km^2, the subspecies' core distribution encompasses approximately 512 km^2 of coastal waters, from estuarine waters of the Houlong and Jhonggang rivers in the north, to waters of Waishanding Jhou to the South (Wang *et al*. 2016). This equates to a linear distance of approximately 170km. However, the main concentration of the population occurs between the Tongshiao River estuary and Taixi, which encompasses the estuaries of the Dadu and Jhushuei rivers, the two largest river systems in western Taiwan (Wang *et al.,* 2007a) (see Figure 2 below). Typically,

the Taiwanese humpback dolphin is found within 3 km from the shore (Dares *et al*., 2014; Wang *et al*., 2016).

Rarely, individuals have been sighted and strandings have occurred in near shore habitat to the north and south of its current confirmed habitat; some of these incidents are viewed as evidence that the population's historical range extended farther than its current range (Dungan *et al.,* 2011). Two specific anomalous sightings are considered incidences of vagrancy, involving sick or dying animals. For example, sightings of animals near Jiang-Jyun Harbour (Tainan County, southwest Taiwan) and Fugang (southeast Taiwan) occurred in 2005. The Fugang sighting occurred in habitat deemed unsuitable for the Taiwanese humpback dolphin, and it is thought that this individual was dying or sick (it has been observed that sick or dying animals of the PRE population stray beyond their normal distribution) (Wang *et al.,* 2007b). All but two sightings have occurred in shallow water, less than 20m, and as shallow as 1.5m. The only two sightings that occurred in water deeper than 20m occurred in habitat where dredging had occurred, thus represents anthropogenic alteration of the dolphin's natural habitat (Wang *et al.,* 2007b). Area of suitable habitat for the dolphin is thought to extend farther to the north and south of confirmed habitat, based on ecosystem characteristics and depth (Ross *et al.,* 2010; Araújo *et al.,* 2014).

The Taiwanese humpback dolphin is thought to be geographically isolated from mainland Chinese populations, with water depth being the primary factor dictating their separation. The Taiwan Strait is 140-200km wide, and consists of large expanses of water 50-70m deep (the Wuchi and Kuanyin depressions). As noted previously, Taiwanese humpback dolphins have never been observed in water deeper than 30 meters, despite extensive surveys. The majority of sightings have been made in waters less than 20 m deep, but individuals have been known to cross deep (>30 m) shipping channels in inshore waters that have been dredged (Dares *et al*., 2014). Thus, deep water is thought to be the specific barrier limiting exchange with Chinese mainland populations (Jefferson and Karczmarski 2001). *Sousa* species in general experience limited mobility, and restriction to shallow, near-shore estuarine habitats is a significant barrier to movement (Karczmarski *et al.,* 1997; Hung and Jefferson 2004). Overall, confirmed present habitat constitutes a narrow region along the coast, which is affected by high human population density and extensive industrial development (Ross *et al.,* 2010; Karczmarski *et al.,* 2016; Wang *et al.,* 2016).

Overall, water depth, access to inshore estuarine waters, and the distribution and availability of prey species are likely the main factors underpinning habitat use and distribution of Taiwanese humpback dolphins (Dares *et al*. 2014; Wang *et al*., 2016). The input of freshwater to the habitat is thought to be important in sustaining estuarine productivity, and thus supporting the availability of prey for the dolphins (Jefferson 2000). Across the Taiwanese humpback dolphin habitat, bottom substrate consists of soft sloping muddy sediment with elevated nutrient inputs primarily influenced by river deposition (Sheehy 2010). These nutrient inputs support high primary production, which fuels upper trophic levels contributing to the dolphin's source of food. The characteristics defining distribution and habitat use of the Taiwanese humpback dolphin are similar to those of other humpback dolphin populations (Dares *et al*., 2014).

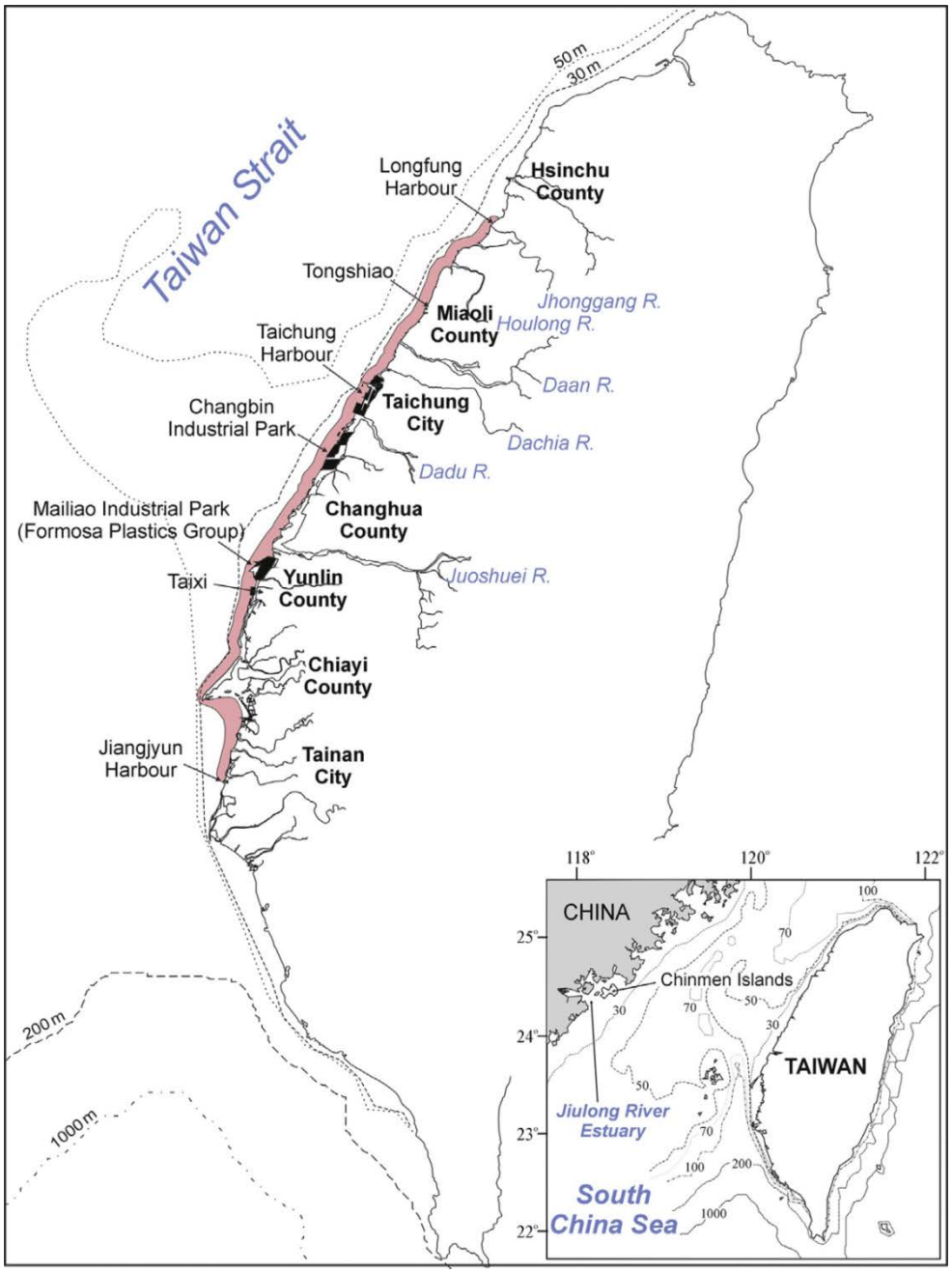

Figure 2 Map of the distribution of the Taiwanese subspecies of humpback dolphins (pink shaded area). Large-scale industrial development projects over coastal waters are represented by black irregularly shaped polygons (Source: Wang *et al.* 2016).

Feeding and Diet

The Taiwanese humpback dolphin is considered a generalist and opportunistic piscivore. Although information on this subspecies' foraging behavior and specific diet is limited, Wang *et al*. (2016) notes that the dolphins seem to have an opportunistic diet of primarily estuarine fish (e.g. sciaenids, mugilids, congrids, clupeoids), and may rarely feed on cephalopods and

crustaceans. While the subspecies does not seem to show the same attraction to fishing vessels as the PRE population, some evidence (e.g., net entanglements and observations of individuals feeding around and behind set gillnets and trawl nets, respectively) indicate that Taiwanese humpback dolphins may opportunistically feed in proximity to deployed fishing gear (Slooten *et al*., 2013; Wang *et al*., 2016). As is common to the species as a whole, the Taiwanese subspecies uses echolocation and passive listening to find its prey. In general, the prey species of the Taiwanese humpback dolphin is believed to include small fish which are generally not commercially valuable to local fisheries (Barros *et al.,* 2004; Sheehy 2009).

Reproduction and Growth

Little is known about the life history and reproduction of the Taiwanese humpback dolphin and estimating life history paramaters for the subspecies has proven difficult due to the lack of carcasses available for study (Wang *et al*., 2016). In some cases, comparison of the Taiwanese humpback dolphin population with other populations may be appropriate, but one needs to be cautious about making these comparisons, as environmental factors such as food availability and habitat status may affect important rates of reproduction and generation time in different populations. A recent analysis of life history patterns for individuals in the PRE population may offer an appropriate proxy for understanding life history of the Taiwanese humpback dolphin; the PRE population similarly inhabits estuarine and freshwater-influenced environments affected by comparable threats of pollution, as well as industrial development and fishing activity (Jefferson *et al.,* 2012). Life history traits of the PRE population are similar to the South African population, suggesting that some general assumptions of productivity can be gathered, even on the genus-level (Jefferson and Karczmarski 2001; Jefferson *et al.,* 2012) (Table 1).

Table 1 Summary of life history parameters for PRE and South African populations of *Sousa chinensis (Sources: Jefferson and Karcsmarski 2001 and Jefferson et al. 2012).*

Parameter	*S. chinensis* (Pearl River Estuary)	*S. plumbea* (South Africa)
Length at birth	101cm	100cm
Age at sexual maturity (females)	9-10yr	10yr
Age at sexual maturity (males)	12-14yr	12-13yr
Asymptotic length	249cm	240cm (F) 270cm(M)
Age at physical maturity	14-17yr	n/d
Maximum longevity	38+yr	40+yr
Maximum length	265cm	>270cm
Maximum weight	240kg	260kg
Peak Calving Season	March-June	Summer
Calving Interval	5yr	3yr

Maximum longevity for PRE and South African populations are at least 38 and 40 years, respectively; thus, it can be assumed that Taiwanese humpback dolphins experience a similar

life expectancy. For example, recent evidence from multi-year photo analysis has demonstrated that apparent survivorship of adults in the population is high, at 0.985 (CI = 0.832-0.998), suggesting that the population is associated with a relatively long life span (Wang *et al.,* 2012).

In general, it has been assumed that the subspecies experiences long calving intervals, between 3 and 5 years (Jefferson *et al.,* 2012). A recent study on the reproductive parameters of the Taiwanese humpback dolphin confirmed this assumption, and estimated the mean calving interval (defined as the period between the estimated birth months of two successive calves) to be 3.26 years ± SD 1.23 years (Chang *et al*., 2016). However, it is important to note that the results of this study are based on only 4 years of data; therefore, females with potentially longer calving intervals would not have been observed or recorded. Gestation lasts 10-12 months, and it has been suggested that weaning may take up to 2 years, and strong female-calf association may last 3-4 years (Karczmarski *et al.,* 1997; Karczmarski 1999). Births occur throughout the year, but decrease in late summer and through mid-winter, with 69% of the estimated months of birth occurring in spring and summer (Chang *et al*., 2016). In terms of survival, less than 3 calves survive annually to the age of 1-year, with survival of calves declining across the initial three years of life from 0.778 at the age of 6-months to 0.667 at 1 year, 0.573 at 2 years and 0.563 at 3 years of age (Chang *et al.,* 2016). Chang *et al*. (2016) hypothesized that the relatively low calf survival observed in the Taiwanese humpback dolphin population is more likely due to anthropogenic factors (e.g., fisheries interactions and habitat destruction) rather than natural causes. Overall, the Taiwanese humpback dolphin is likely long-lived, slow to mature, and has low recruitment rates and long calving intervals. These life history parameters indicate slow population growth, which renders the subspecies very limited in terms of its capacity to resist anthropogenic stress (Chang *et al.,* 2016).

Social Structure and Behavior

In general, humpback dolphin (*Sousa* spp.) populations are known for having generally weak, fluctuating associations in 'fission–fusion' societies (Dungan *et al*., 2016; Wang *et al*., 2016; Dungan 2011; Jefferson 2000). However, a recent study of association patterns in Taiwanese humpback dolphins found that the Taiwanese subspecies exhibits stronger, persistent relationships among individuals, particularly among cohorts of mother-calf pairs (Dungan *et al*., 2016), with a unique level of stability in the population compared to other humpback dolphin populations (Wang *et al*., 2016). In the Taiwanese subspecies, short-term associations, like those similar to the fission–fusion structure observed in other humpback dolphin populations, seem to occur on a scale of hours or days, whereas long-term associations among individuals are very stable, lasting for years (Dungan *et al.,* 2016; Wang *et al.,* 2016). This high social cohesion is most likely related to cooperative calf rearing, wherein raising offspring with the assistance of peers or kin can increase offspring survivorship and thereby increase the fitness of the population (Dungan *et al*., 2016). This behavior is thought to be an adaptive response to the dolphin's degraded, geographically restricted environment (which makes it difficult for mothers to support offspring on their own), and to their small population size (which has likely increased the relatedness of individuals) (Dungan 2011). Calves and their inferred mothers seem to have central positions in the social network, which suggests that mother–calf pairs may be the key

underlying factor for overall network structure (Dungan *et al*., 2016). Given the subspecies' unique cohesive social network, persisting associations, and the reliance on cooperative rearing behaviors of mother–calf groups, disruption of these social patterns could have significant ramifications on the dolphin's ability to reproduce and overall calf survivorship (Dungan *et al*., 2016), which is already reportedly low (Chang *et al*., 2016). Thus, given the unique situation of this particular subspecies as compared to other *Sousa* spp., it appears that maintaining the dolphin's current social structure may be critical to the Taiwanese humpback dolphin's survival.

Population Abundance and Trends

There are only two scientific estimates of abundance for the Taiwanese humpback dolphin. The first, based on surveys conducted between 2002 and 2004 using line transects to count animals, estimated population size at 99 individuals (CV=52%, 95% CI = 37-266) (Wang *et al.,* 2007b) The 2007 international workshop on the conservation and research needs of the Taiwanese humpback dolphin population suggested that the true number of individuals may be lower than this estimate (Wang *et al.,* 2007a). A re-analysis of population abundance conducted on data collected between 2007 and 2010 using mark-recapture analyses of photo identification data allowed for higher-precision measurements. Yearly population estimates from this study ranged from 54 (in 2009) to 74 individuals (in 2010; CV varied from 4% to 13%); these estimates were 25% to 45% lower than those from 2002-2004 (Wang *et al.,* 2012). For the Indo-Pacific humpback dolphin species, it is estimated that mature individuals comprise 60% of the population (Jefferson 2000); based on this proportion, and the largest estimate of population size from the most recent study (74 individuals), the Taiwanese humpback dolphin population is most likely comprised of less than 45 mature individuals, and is the smallest known dolphin population of the taxon. In comparison, estimated abundance of *S. chinensis* in the PRE (the largest known population) is 2,500 individuals (Chen *et al.,* 2008; Chen *et al.,* 2010). For the Taiwanese humpback dolphin, Wang measured survivorship for the population, which was used to determine a mortality rate of 1.5% (±0.022) (Wang *et al.,* 2012; Araújo *et al.,* 2014). Carrying capacity for the Taiwanese humpback dolphin has been estimated at 250 individuals (which was set higher than the highest point estimate abundance from Wang *et al.,* (2012), as extrapolated from the mean density estimate for the population (Araújo *et al.,* 2014); this estimate suggests that the population abundance has been greatly reduced from historical levels.

Recently, an analysis of potential biological removal (PBR), which is a measure of the maximum number of individuals that can be removed from a population without depleting it (Wade 1998), was conducted to assess the sustainability and stability of the Taiwanese humpback dolphin in the face of present threats, and their projected future trends (Slooten *et al.,* 2013). Using the most current abundance estimate, and assuming that the Taiwanese humpback dolphin population is a closed and discrete population (Wang *et al*., 2012), the authors assessed the number of individuals in the population that may be lost due to occurrences other than natural mortality and still allow for population stability and recovery. The authors calculated that a maintaining a sustainable population would require no more than one human-caused

dolphin death every 7 to 7.6 years. Thus, even a single mortality event a year exceeds the sustainable PBR by a factor of seven (Slooten *et al.,* 2013). Their assessment took into account all non-natural mortality including fishing, pollution, vessel strikes, habitat destruction, and other human activities, and determined that current removal of individuals from the population exceeds the PBR necessary for population stability which would permit recovery, prevent decline, and support natural population growth (Slooten *et al.,* 2013). Given the population's mortality rate of 1.5% (Wang *et al.,* 2012), current rates of population decline are considered unsustainable.

Extremely low population size (fewer than 100 individuals) is well supported by current available data, and recent population viability analyses (PVAs) suggest that the population is declining due to the synergistic effects of habitat degradation and detrimental fishing interactions (Araújo *et al.,* 2014; Huang *et al.,* 2014). Araujo *et al*. (2014) modeled population trajectory over 100 years using demographic factors alongside different levels of mortality attributed to bycatch, and loss of carrying capacity due to habitat loss/degradation. The model predicted a high probability of ongoing population decline under all scenarios. For instance, population size was predicted to be smaller than the initial size in more than 76% of all model runs. The final population size was predicted to be <1 individual (i.e., extinction) in 66% of all model runs (Araújo *et al.,* 2014). When considering loss due to fishing bycatch alone, the model predicted a reduction in population size in up to 92.6% of model runs. The model predicted that fisheries interactions had a more immediate threat on the declining population trend than habitat loss (Araújo *et al.,* 2014). However, the authors note that effects on the population due to habitat loss may be more complex than captured in the model; for instance, the model accounted for habitat loss in terms of reduction of carrying capacity for the population. Loss of habitat may lead to social fragmentation and decrease prey availability, effects not captured in the model. In general, the authors consider their results an underestimate of population decline because data are lacking to account for additional loss of individuals and fecundity related to such factors as habitat degradation, pollution, and river diversion (Araújo *et al.,* 2014). Therefore, the negative model trends in population abundance may be underestimates of true trends.

Another PVA was performed by using an individual-based model to account for parametric uncertainty and demographic stochasticity (Huang *et al*., 2014). Although this model showed wide variation in population growth estimates (ranging from a significant decline of -0.113 to a moderate increase of 0.0317), the subspecies still exhibited an overall decline, with 69.4% of simulations predicting a population decline of greater than 25% within one generation (i.e., 22 years) and the majority of simulations (54%) predicting local extinction within 100 years. This study also quantified the subspecies' risk of extinction due to mortality via incidental bycatch and habitat degradation. In contrast to the previous PVA, Huang *et al*. (2014) found that scenarios of habitat loss had a greater impact on the subspecies' population trajectory than bycatch. However, Wang *et al.* (2016) noted that the differences between the results of the two studies in terms of the relative importance of habitat loss and bycatch are due to very different input values used in the simulations, notably the subspecies' carrying capacity (K) and calving interval. Nonetheless, Huang *et al.* (2014) similarly state that their results likely underestimate

the actual rate of decline and risk of extinction because impacts from bycatch and habitat loss are likely higher than what was presented in their study. Additionally, the authors note that while genetic data is lacking for the Taiwanese humpback dolphin, their low population size is well below the minimum number necessary (i.e., at least 250 adults; see original citations in Huang *et al.,* 2014) for marine mammals to resist stochastic genetic diversity loss. Thus, if genetic data were available, the authors assumed their results would likely generate predictions of higher extinction risk than what they reported (Huang *et al.,* 2014).

Knowledge of abundance and demographics of the population relies upon mark-recapture analyses of photo identification data. While this analysis provides a more precise estimate of overall population size than previous survey methods, year-to-year fluctuations in population estimates are more likely related to the quality of sampling and survey effort (e.g., survey time and photo quality permitted by good weather) rather than true shifts in population size over the years examined (Wang *et al.,* 2012). Future monitoring using high-precision survey methods (e.g., mark-recapture of photo identification data) is essential to track changes in the population over time, especially given the numerous and increasing threats to the population and its habitat (Wang *et al.,* 2012). Overall, although the two PVA studies differed in their findings with regard to the relative importance of bycatch and habitat loss threats, both assessments agreed that the subspecies is in serious danger of going extinct in the near future (Wang *et al*. 2016). Ultimately, strong evidence suggests that the population is small, and rates of decline are high, unsustainable, and potentially even underestimated. Further, it is clear that loss of only a single individual within the population per year would substantially reduce population growth rate (Dungan *et al.,* 2011)

ANALYSIS OF THE ESA SECTION 4(a)(1) FACTORS

The ESA requires that five factors, or "threats," and their impact on the species be considered when evaluating its status and risk of extinction: destruction, modification, or curtailment of habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; inadequacy of existing regulatory mechanisms; and other manmade or natural human factors affecting the species' continued existence. In this section, specific threats to the continued existence of the Taiwanese humpback dolphin are examined with regard to these five factors. Where data are available, threats are examined with regard to their past, present, and projected future trends, and how those trends have and will continue to impact the Taiwanese humpback dolphin. As always, threats are examined under the standard of best available science.

Destruction, modification, or curtailment of habitat or range

As discussed earlier in this status review document, the Taiwanese humpback dolphin is an obligatory shallow water inshore species known for its restricted distribution and narrow habitat selectivity; thus, degradation of coastal habitats can have significant consequences for the population, including impacts to persistence and distribution of the subspecies (Karczmarski *et al*., 2016). Like many estuarine habitats, that of the Taiwanese humpback dolphin is

negatively impacted by highly concentrated human activity. Out of Taiwan's human population of 23 million, approximately 90% live in counties bordering the west coast of Taiwan, and thus abutting the Taiwanese humpback dolphin's habitat (Ross *et al.,* 2010). In addition to high population density, the coastal region is associated with persistent industrial development, land reclamation, and freshwater diversion, all of which destroy and degrade estuarine habitat upon which the Taiwanese humpback dolphin depends (Sheehy 2009; Thamarasi 2014). Below, we discuss several factors that may be contributing to the destruction, modification, or curtailment of the Taiwanese humpback dolphin's habitat and/or range, including coastal development/land reclamation, freshwater diversion, and contaminants/pollutants.

Coastal development/Land reclamation

Industrial activity and coastal development contribute to widespread loss and degradation of Taiwanese humpback dolphin habitat. Over the past three decades, the west coast of Taiwan has undergone large alterations of coastal environments due to embankment, land reclamation, coastal construction, and shoreline development, including the construction of break-walls and dredging activities. These activities have increased over the last fifty years and are expected to continue into the future (Wang *et al.,* 2004a; 2007a; Karczmarski *et al.,* 2016). Already, land reclamation has resulted in extensive loss of native estuarine habitat across the Taiwanese humpback dolphin range, and appears to be largely unregulated. For example, actions taken to control for erosion and flooding, as well as the expansion of structures such as fishing ports, power plants, and other public facilities, resulted in a 20% decline in natural coastline within the Taiwanese humpback dolphin's habitat from 1995-2007 (Wang et al., 2004a; 2007a). These activities result in complete and irreversible elimination of already restricted suitable habitat for the Taiwanese humpback dolphin.

With over 600 factories located within a kilometer of the shore on the western coast of Taiwan, industrial development is one of the most significant factors contributing heavily to the degradation of vital estuarine and coastal resources upon which the Taiwanese humpback dolphin depends. Offshore wind farm development (now underway) and additional reclamation for industrial parks and municipal activity have recently been proposed, which would result in additional loss of habitat; it is unclear whether these plans will be denied or mitigated for the purpose of conserving the subspecies. A discussion of future development plans was presented to the 2007 Taiwanese humpback dolphin conservation workshop, and recently updated at the 2014 Taiwanese humpback dolphin conservation working group meeting; dozens of these development plans are either currently underway or poised for the near future, and propose wide-scale land reclamation and water diversion (Wang *et al*., 2007a).

Current and ongoing industrial and coastal development threatens to eliminate large portions of the dolphin's habitat. For example, a recent study analyzed land use changes that occurred between 1996 and 2011 in the western coast of Taiwan, Yunlin county (Thamarasi 2014). While this work did not address changes across the entirety of the Taiwanese humpback dolphin's range, it provides an example of the extent and nature of land use changes occurring throughout the region, and impacting Taiwanese humpback dolphin habitat. The study found that industry and residential lands expanded dramatically over the time period, increasing by 131.87% and 72.03%, respectively. For the most part, these land use changes occurred along the coastline. The increase in industry resulted in a 92.51% decrease in sandy coasts, the most significant land use alteration measured in the analysis. Decrease in sandy habitat was directly related to construction of industrial parks. As is occurring throughout the western coast of Taiwan, Yunlin County experienced an increase in land reclamation, where land accretion seaward resulted in widespread loss of natural coastal habitat and vital near shore ecosystems. The trend in increased industrial and residential development, and land reclamation to support this expansion, has resulted in large-scale land use changes that negatively impact the near shore habitat of the Taiwanese humpback dolphin by directly eliminating its habitat, and introducing new sources of pollution and noise that affect the health of the subspecies. Future plans for development involve removal and reclamation of large swaths of the confirmed Taiwanese humpback dolphin habitat; the largest plans for future coastal development propose to reclaim up to 20% of the dolphin's current habitat (Wang *et al.,* 2007a). These trends are expected to increase in the future unless growing plans for industrial and coastal development are halted.

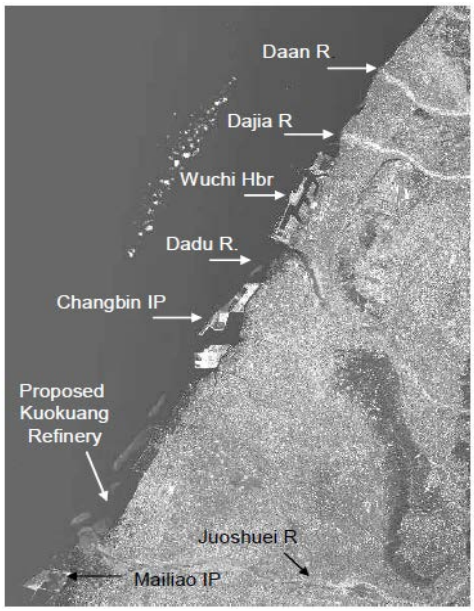

Figure 3. Past coastal land reclamation within Taiwanese humpback dolphin habitat reflecting extensive cumulative impacts from industrial parks and harbor complexes (Sheehy 2009)

More recently, Karczmarski *et al*. (2016) measured the extent of habitat destruction due to land reclamation off the west coast of Taiwan since 1972 and determined that a total area of over 222 km^2 was lost to land reclamation (which equates to 23% of dolphin habitat and 40% of dolphin foraging habitat) as of 2013. The authors note that because they only considered habitat degradation due to land reclamation (and did not consider other impacts to the dolphin's habitat), the actual extent of habitat degradation is likely higher than reported in their study. Karczmarski *et al*. (2016) notes that "The most evident change in coastal landscape involved the degradation of estuarine systems, loss of coastal marshes, and the degradation of shore-oblique sandbars, much of which have been replaced with agriculture, aquaculture, urban and industrial developments, road construction, embankment, slope modification, and

large-scale land reclamations." Additionally, Landsat data show that a wide range of complex aqueous features (essential for both the dolphin and its prey items) stretched uninterrupted along the western coast of Taiwan prior to 1972 (Karczmarski *et al*., 2016). The authors suggest that prior to any major land reclamation activities, the Taiwanese humpback dolphin likely had a continuous distribution, whereas the subspecies' distribution appears to be currently fragmented (see Figure 4; Karczmarski *et al*., 2016). Karczmarski *et al*. (2016) concluded that the current discontinuous distribution of Taiwanese humpback dolphins is likely due to varying levels of habitat degradation rather than "natural patchiness of their environment."

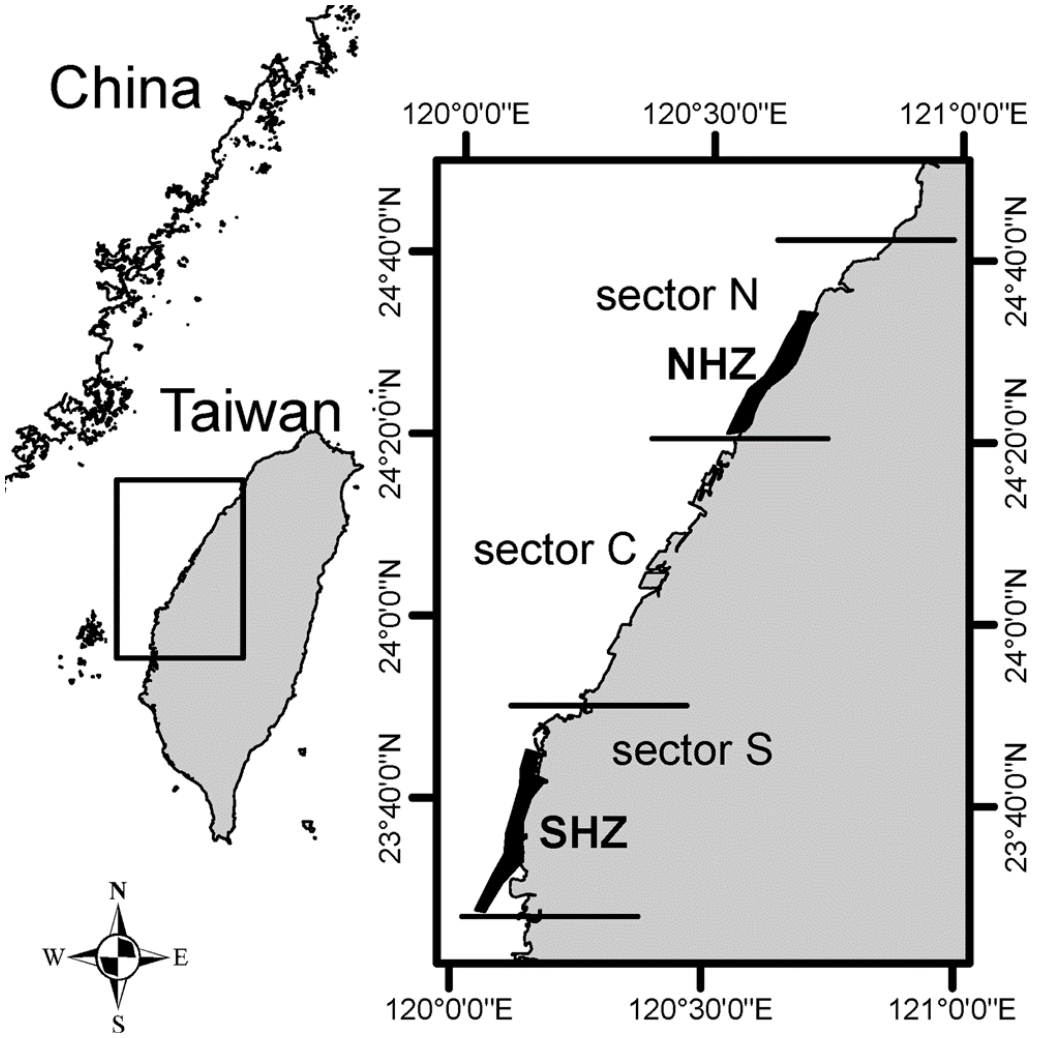

Figure 4 The area inhabited by Taiwanese humpback dolphins (*Sousa chinensis taiwanensis*) along Taiwan west coast. The study area, from 24.73◦ to 23.43◦ N, was further divided into three sectors: north 24.73°–24.33° N (sector N), central 24.33°–23.87° N (sector C), and south 23.87°–23.43° N (sector S). The two hot zones of dolphin distribution (after Chou and Lee 2010) are indicated as NHZ in sector N and SHZ in sector S (Source: Karczmarski *et al*. 2016).

However, Dares *et al.,* (2017) notes a number of issues regarding the study by Karczmarski *et al.* (2016). Dares *et al.* (2017) argues that Karczmarski *et al.* (2016) used a very low spatial resolution to look at their study area and subdivided the study area into arbitrary sectors, which significantly influenced the results. Additionally, analyses regarding how oceanographic

variables may influence sighting distribution, and information on how factors may affect density per unit effort (as opposed to encounters) in their sectors are lacking. Dares *et al*. (2017) found Taiwanese humpback dolphins exhibited temporal and spatial variation in mean densities across their range, and that dolphin density was not directly linked to any environmental factors (e.g., depth, sea surface temperature, salinity, and proximity to the nearest source of fresh water). In fact, all metrics analyzed in the study, including dolphin sightings, dolphin density, and mother-calf pairs, were higher in waters adjacent to major reclamation projects as compared to more natural waters where major reclamation activities had not occurred. The authors discuss a couple of explanations for these unexpected results, including the possibility that dolphin densities in these areas may have always been relatively higher than other parts of the dolphin's range. Additionally, the seeming non-effect of reclamation projects on dolphin density may be linked to the location of reclamation projects (i.e., near the mouths of major rivers) (Dares *et al*., 2017). Unlike other cetacean species, Taiwanese humpback dolphins are confined to a relatively small amount of suitable habitat; therefore, the dolphins do not have the option to relocate to other areas when high quality habitats are degraded or lost to reclamation activities (Dares *et al*., 2017). Thus, the authors conclude that "rather than a real preference for waters adjacent to reclaimed coastlines" the patterns observed in the study are likely due to the fact that the locations of these large construction sites and activities are in close proximity to the two largest estuaries in the range of the subspecies (Dares *et al*., 2017). However, some caveats to this study should be noted as well. For example, data were only collected during the wet season, when increased rainfall increases freshwater outflow from rivers. As a result, habitat use and distribution patterns may be different in drier months, where there is less freshwater input in the study area (Dares *et al*., 2017).

Despite the differences in distribution and habitat use observed in these recent studies, the large elimination of suitable habitat affects the Taiwanese humpback dolphin in several ways. First, habitat fragmentation due to high levels of industrial development may reduce connectivity among estuaries along the narrowly distributed range of the population. This can physically limit the ability of individuals to associate with each other, which could have detrimental impacts on the dolphin's reproductive output and calf survivorship, particularly given the subspecies' high social cohesion and dependence on cooperative calf-rearing behaviors (Dungan *et a*l., 2016). Next, waste discharge from industrial activity leads to water and sediment contamination. Given the extremely limited availability of suitable habitat for the dolphin, use of lower quality habitat near coastal developments because of land reclamation can also expose the dolphins to areas of higher effluent discharge and pollutants (Dares *et al.,* 2017). Finally, dredging and hydraulic sand fill methods used frequently for industrial land reclamation in the area not only encroach upon limited habitat, but they also have the potential to disrupt the distribution of vital prey species of the population (Ross *et al.,* 2010; Dungan *et al.,* 2011).

Freshwater Diversion

The Taiwanese humpback dolphin is dependent upon freshwater inflow to support the productivity and ecosystem health of its estuary habitat. This habitat need is similar to that of

the PRE population, where freshwater inflow has been shown to support steady estuarine ecosystem production upon which the dolphin relies for prey (Jefferson and Hung 2004). Freshwater flow is drastically reduced by dams, flood control, and river diversions related to industrial development and diversion for agricultural and municipal purposes (Dungan *et al.,* 2011). In Taiwan, freshwater flow from all major rivers to estuaries has decreased by as much as 80% due to anthropogenic diversion (Ross *et al.,* 2010). Landsat data also shows a drastic reduction and weakening of annual discharge from major rivers along Taiwan's west coast since 1972, as indicated by the reduced width of the channel and alluvial fans at river mouths (Karczmarski *et al.*, 2016). The reduction of freshwater flow reduces soft-bottom habitat and sedimentation occurring in the estuaries and coastal areas where the population occurs. This can alter the functionality of a coastal area from valuable to marginal or even avoided, which may be the case for the area off the central sector of Taiwan's west coast (refer back to Figure 4; Karczmarski *et al*., 2016). Dams are already in place for many rivers in Western Taiwan, and have resulted in widespread loss of estuarine mudflat habitat, vital to Taiwanese humpback dolphin foraging and productivity. For example, the Coshui (=Juoshuei) River which once supplied sediment to the Waisanding sand bar, has been diverted and restricted by the Formosa Petrochemical Corporation plant, resulting in shifts and shrinking of the sand bar (Chen 2006). Taiwanese dams and their total capacity have increased exponentially over the past century, resulting in significant loss and alteration of natural estuarine systems (Figure 5).

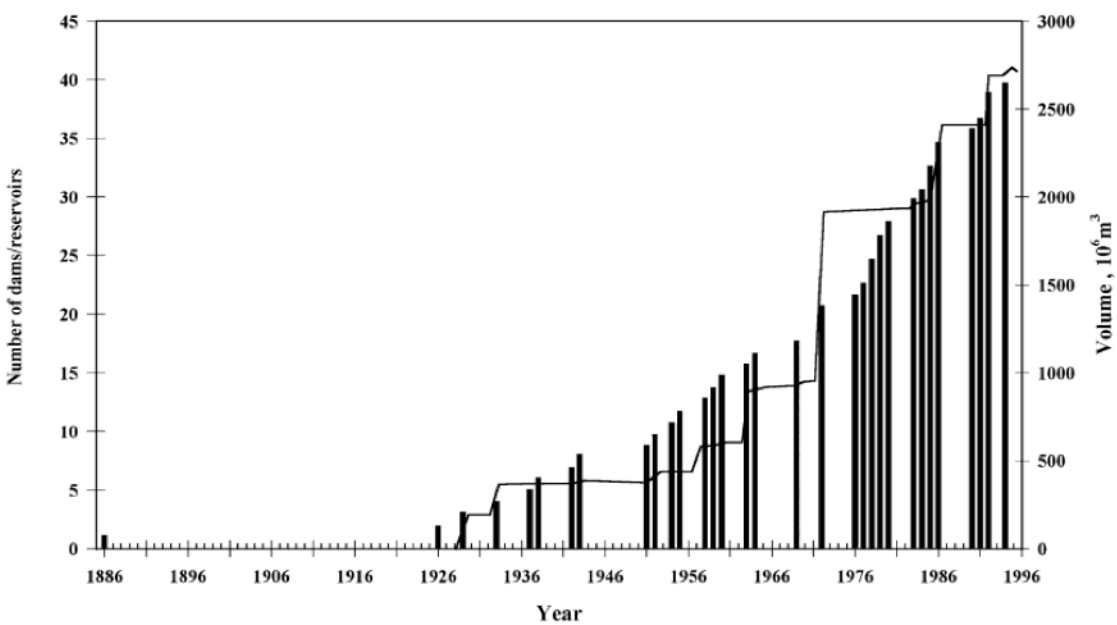

Figure 5. Number of dams/reservoirs and their total capacity in Taiwan since 1886. From: Chen *et al.,* (2004).

In many ways, the reliance upon freshwater input of the humpback dolphin mirrors the needs of another threatened small cetacean species (the Baiji of China, now declared extinct). It is the

reliance upon freshwater input, proximity to downstream pollution, and anthropogenic impacts that contribute heavily to the decline of these species, and immediate extinction risk (Ross *et al.,* 2010).

Contamination/Pollution

Pollution and habitat contamination pose a threat to the health of long-lived species such as the Taiwanese humpback dolphin. Due to concentrated industrial and human activity, high levels of pollution are discharged into the habitat of the Taiwanese humpback dolphin (Wang *et al.,* 2007a). The sources of these pollutants include marine boat repair, fish processing, fueling stations, ship dumping, pipeline leakage, municipal and residential waste, industrial effluent, and livestock runoff (Ross *et al.,* 2010). The discharge of toxic pollutants into coastal waters of Taiwan is largely unregulated. For instance, an estimated 740,000 tons of waste oil from boats enters the marine environment in Taiwan each year (Wang *et al.,* 2007b). In addition, over 70% of wastewater is discharged into river systems untreated, and subsequently runs off into near shore estuarine habitat (Chen *et al.,* 2007). Particularly damaging are persistent organic, heavy metal, and trace metal pollutants which negatively interact with cetacean development and reproduction and are associated with carcinogenic and teratogenic properties (Reijnders 2003; Ramu *et al.,* 2005). These toxins have been found to accumulate and become concentrated in the marine sediment off the coast of Taiwan affected by freshwater input, impacting the Taiwanese humpback dolphin habitat (Chen *et al.,* 2007; Hung *et al.,* 2010). Even toxins which were banned in the 1980's, such as polychlorinated byphenyls (PCBs), remain present in poorly maintained machinery and industrial equipment, thus their accumulation is expected to continue in the future (Chou *et al.,* 2004). For instance, Hung found that sediment PCB concentrations were highest at the mouths of rivers, at concentrations as high as 51.51 ng g^{-1} (Hung *et al.,* 2010). Given the growing trend in industrialization, the accumulation and release of toxins in the Taiwanese humpback dolphin habitat is an immediate threat expected to continue, and increase, in the future.

Organochlorides are some of the most toxic contaminants thought to affect the humpback dolphin in Chinese waters; these toxins include polychlorinated biphenyls (PCBs), hexachlorocyclohexane HCHs, and DDTs (Parsons 2004; Jefferson *et al.,* 2006). Historically in China, DDT was used extensively as an inexpensive pesticide, and while now banned, illegal use may continue today as suggested by its continued detection in humpback dolphins and sediment off the coast of Hong Kong (Jefferson *et al.,* 2006). PCBs in the marine environment originate from multiple sources, including the manufacture of paint, plastics, adhesives, electrical equipment, etc. These compounds can persist in the environment for many years, and bioaccumulate throughout the food web and within the blubber of cetaceans throughout their lifetime; these chemicals are passed down from one generation to the next, transported via milk from the mother to calf (Fowler 1990; Hung *et al.,* 2006). Cetaceans have a low capacity to metabolize these compounds, which can interfere with reproduction, lead to immunosuppression, and are associated with carcinogenic and terratogenic (developmental) effects (Reijnders 2003). Pollution can affect the Taiwanese humpback dolphin in two ways: directly influencing the health of the animal or influencing prey that the dolphin later ingests, thus leading to bioaccumulation of the toxin in the dolphin (Figure 6).

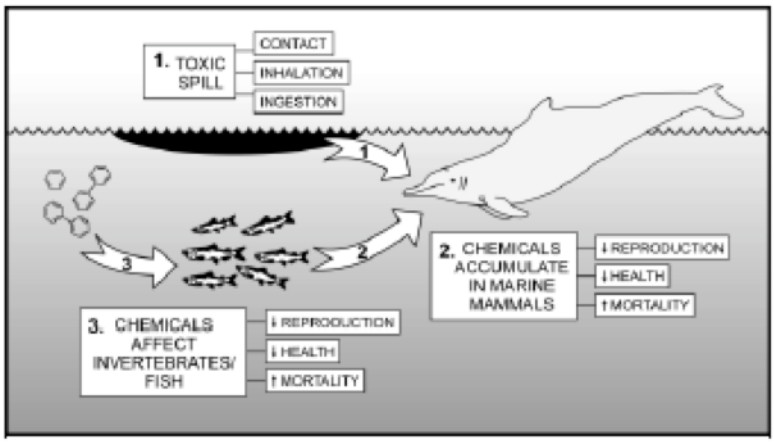

Figure 6. A schematic diagram showing a simplification of the food web for humpback dolphins (provided by Peter S. Ross)

To date, only one study has analyzed the potential bioaccumulation of toxins specifically for the Taiwanese humpback dolphin population. Riehl *et al*. (2012), using a life-history based contaminant accumulation model for marine mammals, estimated that 68% of the population is at risk for immunotoxicity based on a 17 mg/kg lipid weight (LW) threshold for immunotoxicity (noting that there are several lower level thresholds shown to impact the health of marine mammals). Model outputs using a "best-case" scenario (e.g., diet of 100% *Johnius* spp.) resulted in average adult males reaching the threshold concentration just prior to turning 9.3 years of age. In contrast, the average adult female would only acquire enough PCBs to reach concentrations of 2.84 mg/kg LW due to offloading much of their body burden to their offspring after giving birth (Riehl *et al*., 2012). Although the study was based on limited species-specific data inputs to the model, humpback dolphins in the PRE, affected by similar threats of industrial development and habitat contamination, have demonstrated elevated concentrations of organochlorines including polychlorinated biphenyls (PCBs), hexachlorocyclohexane HCHs, and DDTs (Parsons 2004; Ramu *et al.,* 2005; Jefferson *et al.,* 2006). For example, in humpback dolphins off the coast of Hong Kong, the concentration of DDTs was as high as 470 µg/g LW, and PCBs as high as 78 µg/g (Ramu *et al.,* 2005). Toxicity analysis (which compares these concentrations with known toxic effects from other marine mammals) strongly suggests that these chemicals impair reproduction and suppress immune function in the Indo-Pacific humpback dolphin (Ramu *et al.,* 2005) (Figure 7).

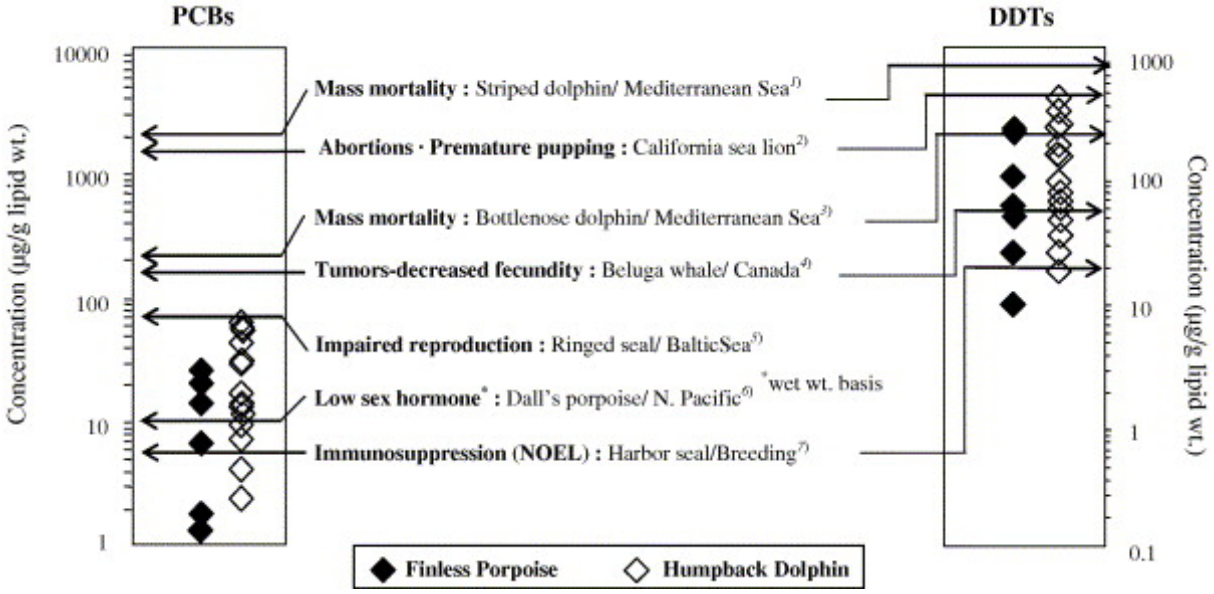

Figure 7. Toxic assessment of PCBs and DDTs in cetaceans from Hong Kong coastal waters. Data were cited from (1) (Kannan *et al.,* 1993) (2) (DeLong *et al.,* 1973)(3) (Corsolini *et al.,* 1995)(4) (Martineau *et al.,* 1987) (5)(Helle *et al.,* 1976) (6)(Subramanian *et al.,* 1988) (7) (De Swart *et al.,* 1996). *: wet weight basis. From (Ramu *et al.,* 2005)

In addition, humpback dolphins exhibited alarmingly high levels of methylated mercury in waters off of Hong Kong (Hung and Hsu 2004). In fact, humpback dolphin populations that inhabit near shore estuaries off the coast of China have demonstrated higher concentrations of these toxins than the finless porpoises (genus *Neophocaena*) that inhabit waters farther off-shore, suggesting that proximity to nearshore run-off sources of pollution, such as those found in high abundance in Taiwanese waters, may lead to greater contamination in this species (Hung *et al.,* 2006). In general, young dolphins and neonates make up a greater proportion of stranding specimens in Chinese waters; it is thought that the higher stranding of young individuals is related to high concentrations of organochlorines found in their tissues (Parsons 2004; Jefferson *et al.,* 2012). Although no extensive analysis has measured toxin concentrations in individuals of the Taiwanese humpback dolphin population, contamination trends similar to those observed in the mainland Chinese populations can be expected based on comparable life history, dependence on estuarine productivity, proximity to freshwater input, and industrialization within its range. Because of this, it is likely that pollution and contamination affect reproductive rates and health of the population.

Concentration of contaminants has been examined in a variety of cetacean species that were either stranded or victims of bycatch in Taiwanese waters (Chou 2002, Chou 2004), but only in one Taiwanese humpback dolphin individual (Chou *et al.,* 2004). All individuals examined show evidence of organochloride and mercury toxicity, demonstrating that habitat pollutants are bioaccumulating in local marine mammals (Chou *et al.,* 2004; Chen *et al.,* 2005; Chen *et al.,* 2007). In a recent study documenting skin conditions of the Taiwanese humpback dolphin, 37%

of individuals showed evidence of fungal disease, various lesions, ulcers, and nodules (Yang *et al.,* 2013). The authors suggest that the high prevalence of compromised skin condition may be linked to high levels of environmental contamination (Yang *et al.,* 2013). Despite the need for further monitoring of toxins in the Taiwanese humpback dolphin population, evidence suggests that widespread habitat contamination is leading to the bioaccumulation of toxins within individuals; these toxins are known to compromise marine mammal reproduction and immune response, and are most likely negatively impacting the health and viability of the population.

Overutilization for commercial, recreational, scientific, or educational purposes

Whale watching

While some whale watching and recreational observation of marine mammals off the coast of Taiwan does occur, it is unlikely that these activities contribute heavily to the extinction risk for the Taiwanese humpback dolphin, relative to other threats. However, some tours targeting the Taiwanese humpback dolphin have been permitted to operate despite recommendations against any boat-based dolphin watch tour targeting the subspecies (Wang, Pers Comm. 2017; Wang *et al*., 2007a). Therefore, while whale watching tours on their own are unlikely to pose a significant threat to the dolphin, any additional stressor on the population likely acts synergistically with other more prominent threats and contributes to the subspecies' extinction risk.

Scientific monitoring

It is also unlikely that scientific monitoring has a negative impact on the Taiwanese humpback dolphin. The dolphin was only first observed in 2002, and since then several scientific surveys have sought to characterize its status and abundance. The low frequency of these surveys, and reliance on non-invasive photo identification, are unlikely to pose serious threats to the subspecies.

Disease or Predation

While there have not been any direct observations of parasites in the Taiwanese humpback dolphin, a handful of parasites have been identified that affect the Indo-Pacific humpback dolphin. Internal parasites include the nematode *Anisakis alexandri* (Dailey and Brownell 1972; Hsu and Hoeppli 1993) and *Halocerus pingi* (Gibson and Harris 1979), which affect the stomach and liver, respectively. Individuals affected by the lungworm *Halocercus pingi* and trematodes (unknown species which affect the eye) have been identified in the population in waters off Hong Kong (Parsons 1997), and may affect the Taiwanese humpback dolphin as well. However, there is currently no data to determine whether these parasites negatively affect the health or population status of the Taiwanese humpback dolphin specifically.

Increased interaction with anthropogenic activity, and close proximity to Taiwan's dense human population, could put the Taiwanese humpback dolphin at increased risk of pathogen exposure; this negative interaction has been observed in other *Sousa chinensis* populations (Parsons and Jefferson 2000). International trade or travel and increasing human activity in the region most likely facilitate the introduction of invasive species and new pathogens to Taiwanese waters. In addition, stress derived from close interaction with boating, industry, noise, and fishing likely

impairs the immune response of Taiwanese humpback dolphin individuals. However, direct impacts of increased pathogen exposure and decreased immune health are unknown.

In terms of predation, sharks are known predators to the Indian Ocean humpback dolphin (*S. plumbea*), and have been responsible for several known attacks in South Africa (Cockcroft 1991). Humpback dolphins have been known to react to sharks, demonstrating either avoidance or aggressive behavior (Saayman and Tayler 1979). Humpback dolphin individuals demonstrate avoidance behavior in the presence of killer whales; however, predation by killer whales has not been documented (Saayman and Tayler 1979; Jefferson and Karczmarski 2001). While no evidence exists documenting shark attacks on Chinese populations of the humpback dolphins, it is probable that sharks pose a predatory threat across the species' range. However, predation by sharks in coastal waters of Taiwan is not likely a major source of mortality and injury for the Taiwanese humpback dolphin.

Inadequacy of Existing Regulatory Mechanisms

The Taiwanese humpback dolphin is listed under Taiwan's Wildlife Conservation Act as a Level I protected species, which grants species the highest level of legal protection. Article 4 of the Act designates humpback dolphins as "protected wildlife", and Article 18 states that these animals are "not to be disturbed, abused, hunted [or] killed" (Wang *et al.,* 2016). Nonetheless, there appear to be no associated regulatory or enforcement actions for the prevention of bycatch and entanglement of the population, or extensive habitat degradation (Wang *et al*., 2016). For example, several years after Ross et al. (2010) published recommendations for legally protecting the confirmed and suitable habitat for the Taiwanese humpback dolphins, the Forestry Bureau of Taiwan proposed "Major Wildlife Habitat" for the dolphins in 2014; however, the proposed protected area did not cover the minimum area recommended for protection (Wang *et al*., 2016). Given the already restricted amount of suitable habitat available to the dolphin, providing legal protection for an area that doesn't cover the subspecies' entire distribution may put the dolphins at increased risk of encountering threats occurring just outside the protected area (also known as the "edge effect"; see original citations in Wang *et al.,* 2016). Furthermore, regardless of potential inadequacies of the proposed protected area, the "Major Wildlife Habitat" proposal has yet to be implemented (Wang *et al*., 2016). Therefore, based on current knowledge of the population, and despite providing the highest level of legislative protection, the Wildlife Conservation Act appears inadequate to control the primary threats to the species and has thus far proven unsuccessful in slowing population decline.

All *Sousa* spp., including the Taiwanese subspecies, are listed under Appendix I of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES). The CITES Appendix I regulates species in order to reduce the threat of international trade. Appendix I addresses those species deemed threatened with extinction by international trade and CITES prohibits international trade in specimens of these species except when the purpose of the import is not commercial, meets criteria for other types of permits, and can otherwise be legally done without affecting the sustainability of the population, for instance for scientific research. In these exceptional cases, trade may take place provided it is authorized by the

granting of both an import permit and an export permit (or re-export certificate). However, there is no evidence that trade of the Taiwanese humpback dolphin is occurring. In this respect, the CITES listing is not failing in its mission.

The pesticide DDT, a known endocrine disrupter of many organisms (including cetaceans), is technically banned in China and Taiwan, but evidence suggests it continues to be used illegally. Measurements of pollution composition and its historical trends have indicated ongoing fresh DDT input into Chinese and Taiwanese waters (Parsons 2004; Jefferson *et al.,* 2006; Doong *et al.,* 2008). It is likely that DDT continues to be used, and that existing regulatory mechanisms are currently inadequate in preventing continued loading of DDT into the Taiwanese humpback dolphin ecosystem, and its subsequent bioaccumulation.

While many recommendations have been made to guide the future conservation and recovery of the population (Wang *et al.,* 2004a; 2007a; Ross *et al.,* 2010; Ross *et al.,* 2011), no current regulatory mechanism is in place to address the major threats to the subspecies and its future viability. Development and industrialization of the region are largely unregulated. Fishing and marine mammal bycatch is also unregulated. In fact, fishing along the western coast of Taiwan is heavily supported by the Taiwanese government, due to fuel subsidies for boats actively fishing for >90 days per year (examples from ETSSTAWG, 2014).

Other natural or human factors affecting continued existence

Bycatch and entanglement by fishing gear

Entanglement and mutilation due to interactions with fishing gear are likely the most serious direct and immediate threat to the Taiwanese humpback dolphin (Wang *et al.,* 2016; Wang *et al*., 2017). Bycatch poses a significant threat to small cetaceans in general, where entanglement in fishing gear results in widespread injury and mortality (Read *et al.,* 2006). Taiwanese fisheries reports indicate that entanglement in fishing gear kills thousands of small cetaceans in the region (Chou 2006). Although there are many types of fishing gear used throughout the subspecies' habitat, the two fishing gear types most hazardous to small cetaceans are gillnets and trammel nets, thousands of which are set in coastal waters off of western Taiwan (Dungan *et al.,* 2011; Slooten *et al.,* 2013).

Figure 8. Entangled or seriously injured dolphins photographed in 2012. From top to bottom: a fishing line around the torso of a young calf; an individual dragging two pieces of fishing line embedded into and slicing through the dorsal fin, with a large healed scar below and anterior to the base of the dorsal fin on the left side; an individual exhibiting many healed linear injuries on the tail, several of which were not observed in previous years; and an individual with a very fresh serious injury behind the dorsal fin. Source: Wang (2013) progress report.

Injury due to entanglement is evident in the Taiwanese humpback dolphin population, identified by characteristic markings on the body, including constrictive line wraps, and direct observation of gear wrapped around the dolphin (Slooten *et al.,* 2013). One study determined that over 30% of the Taiwanese humpback dolphin population exhibits evidence of fisheries interactions including wounds, scars, and entanglement (Wang *et al*., 2007a; Slooten *et al*., 2013), with 59.2% of injuries (lethal and non-lethal) observed were confirmed to have originated from fisheries interactions (Slooten *et al.,* 2013). Even in non-lethal interactions, injuries sustained due to encounters with fishing gear may lead to mortality via immunosuppression, stress, and malnutrition, although these effects are not easily measured (Dungan *et al.,* 2011); this

measurement likely underestimates the full extent of the threat, and the prevalence of internal damage from ingestion of fishing gear could not be determined (Slooten *et al.,* 2013). In a more recent study that expands upon Slooten *et al*. (2013), Wang *et al*. (2017) determined that 60% of the individuals examined in the study (n = 78) bore major injuries caused by human activities, with a total of 93 major injuries recorded on 46 individuals. Not only was a large proportion of the population injured, more than half of the individuals suffered multiple injuries, with several new injuries observed. Consequently, this means that the risk of injury by human activities is ongoing. In fact, from 2007 to 2015, 11 new human-caused injuries were recorded on 9 individuals. Therefore, each year, the population incurred 1.38 new injuries and 1.13 individuals were newly injured (Wang *et al.,* 2017). However, the authors note that despite the fact that all metrics evaluated in the study were high, they were still likely underestimates of the total impacts. For example, fatal injuries in which the animals dies immediately or soon after could not be considered and thus not factored into the overall measure of impact. Two individuals have been found dead since 2009 with indications of gillnet entanglement injuries (Wang *et al*., 2017) and thus far, there has been no action to reduce any of the major threats identified more than a decade ago at the first workshop on the conservation and research needs of the subspecies (Wang et al., 2004a; Wang et al. 2017). Overall, without immediate actions to control for threats from local fisheries (especially net fisheries) and other major threats identified to the subspecies, the Taiwanese humpback dolphin likely faces imminent extinction (Wang *et al*. 2017).

In addition to direct effects of fishing activity on the Taiwanese humpback dolphin, indirect effects of fishing include: depletion of prey resources, pollution, noise disturbance, altered behavioral responses to prey aggregation in fishing gear, and potential changes to social structure arising from the deaths of individuals caused by fisheries activity. Individuals of the Taiwanese humpback dolphin have shown evidence of disturbance due to all of these effects (Slooten *et al.,* 2013). For example, recent surveys have observed dolphins with emaciated and poor body condition, suggesting declines in prey abundance, increased foraging effort, or disease (Slooten *et al.,* 2013). While most Taiwanese humpback dolphin prey species are small and not commercially valuable (Barros *et al.,* 2004), decreases in their abundance due to bycatch and subsequent fishmeal production may lead to over-exploitation, and reduce prey availability for the dolphin (Slooten *et al.,* 2013). Fisheries create pollution, including waste disposal, boat exhaust, abandoned gear, and toxic anti-fouling paints, all which lead to declined health an increased mortality of the dolphin (Slooten *et al.,* 2013). Increased prey aggregation due to fishing can attract mothers and calves, putting them at greater risk of entanglement and injury; this has been observed in the PRE population, and is most likely behavior common to the Taiwanese humpback dolphin as well (Jefferson 2000). Finally, death and injury of individuals due to fishing activity can disrupt social structure, which may affect the survival of calves or transference of generational information throughout the social network. For example, loss of a mature female may impact the trajectory of learning and survival techniques passed on to a calf in its first several years.

Vessel strikes
In addition to bycatch and entanglement, fishing activities can also affect dolphins by increasing the likelihood of vessel strikes due to increased boat traffic. The waters off Taiwan are highly concentrated with human boat activity, including transportation, industrial shipping, commercial fishing, sand extraction, harbor dredging, and commercial dolphin watching. This activity is unmitigated, and its concentration has increased dramatically over the past few decades. In fact, the trend in boating and fishing activity in the region has increased by more than 750% since the 1950's, and its increase is expected to continue into the foreseeable future (Huang and Chuang 2010). Fishing vessels alone contribute a large fraction of this boating activity; an estimated 6,300 fishing vessels are currently active inside the dolphins' habitat (operating from ports in the six coastal counties fronting the dolphins' habitat), and 45% of them are regularly engaged in fishing coastal waters (Slooten *et al*., 2013). The fleet is over-capitalized due to technological improvements, and thus fishing pressure, and negative interactions between fishing gear/vessels and cetaceans is increasing (Wang *et al.,* 2007b). Additionally, this traffic is unregulated, and poses a threat to the limited and narrow habitat available to the subspecies. The noise from these vessels may be disorienting for the dolphins, which rely upon acoustic sensory systems to communicate, forage, and interact with their environment, and thus increase the potential for a strike. In addition, individuals, especially females and calves, may be attracted to fishing vessels due to elevated prey concentration, which can lead to mortality via vessel strike. Humpback dolphins off the coast of Hong Kong, which interact with comparable levels of vessel traffic and face similar threats to habitat, have demonstrated unmistakable evidence of propeller cuts on their bodies, and vessel strikes have been determined as the conclusive cause of mortality in a high proportion of stranding incidents (Jefferson 2000).

Aside from direct mortality, interaction with vessel traffic may alter behavior of the dolphin, causing stress, reducing foraging efficiency, increasing the threat of predation, and altering behaviors that support its productivity. For instance, in individuals off the coast of Hong Kong, mother-calf pairs demonstrated the greatest level of disturbance by vessel traffic; it has been hypothesized that separation of the calf due to vessel disturbance could easily increase risk of predation, aside from the direct injury of a vessel strike (Van Parijs and Corkeron 2001).

Acoustic disturbance
Small odontocete cetaceans, including the Taiwanese humpback dolphin, rely upon a highly developed acoustic sensory system and echolocation to navigate, feed, and communicate with other individuals in the marine environment. They are negatively affected by loud and persistent noise in the ocean, which can disrupt everything from the distribution of prey, to their ability to forage and communicate (Richardson and Würsig 1997; Simmonds *et al.,* 2004; Nowacek *et al.,* 2007; Weilgart 2007). Noise disturbance has been shown to illicit a variety of stress responses from other cetacean species, such as the bottlenose dolphin and beluga whale (Gordon and Moscrop 1996; Richardson and Würsig 1997; Nowacek *et al.,* 2007). The Taiwanese humpback dolphin is chronically exposed to noise disturbance from dense boat activity related to commercial and industrial fishing and shipping throughout its habitat. Noise disturbance resulting from development-related activity such as pile-driving, as well as seismic

research and military exercises within its habitat are considered threats to the health and well-being of the population (Ross *et al.,* 2010). Based on extensive cetacean research, prolonged and chronic exposure to noise disturbance experienced by the Taiwanese humpback dolphin may result in loss of hearing and increases in stress hormones leading to hindrance of immune response (Richardson and Würsig 1997; Nowacek *et al.,* 2007; Weilgart 2007). Acoustic disturbance is likely a threat that compounds other threats to the population by decreasing foraging success, increasing stress, and decreasing immune health. Without restrictions on boating and marine industrial activity or equipment, acoustic disturbance to the Taiwanese humpback dolphin population is likely to increase in the future.

Climate Change

Global anthropogenic climate change is responsible for increasing temperatures across the globe on land and sea; the continued trend of this temperature increase is clear, and it is with increasing confidence that the magnitude of change over the next several decades can be predicted (2014 IPCC report). However, the direct effect of warming on the Taiwanese humpback dolphin's physiology, metabolism, ecology and health are not understood, and thus the risk posed by future climate change related impacts are highly uncertain. Nevertheless, indirect effects on the dolphin's habitat and food availability may occur. For instance, warming water would increase evapotranspiration of the rivers, and alter the buoyancy effect of river plumes (Chen *et al.,* 2004). It has been estimated that this warming would reduce upwelling and nutrient supply that support estuarine productivity (Chen *et al.,* 2004). A downstream effect could involve reduction of prey availability for the dolphin. However, climate change does not appear to pose a significant threat to the Taiwanese humpback dolphin at present.

ASSESSMENT OF EXTINCTION RISK

We assessed the extinction risk for the Taiwanese humpback dolphin by considering two types of information: (1) demographic viability characteristics (*e.g*. abundance, growth rate/productivity, spatial structure/connectivity, and diversity) reflecting the dolphin's past and present status; and (2) threats faced by the subspecies (*e.g.*, bycatch, habitat destruction, pollution) as described in terms of the ESA 4(a)(1) factors.

Demographic characteristics of, and threats to, the Taiwanese humpback dolphin, now and in the foreseeable future, were used to estimate the overall risk of extinction. We analyzed the contribution of each factor to the risk of extinction separately and considered the synergistic effects of all relevant factors. Specifically, we accounted for demographic information including abundance, growth rate/productivity, spatial structure/connectivity, and diversity of the subspecies as described in Wainwright and Kope (1999) and McElhany (2000); these factors are thought to be good indicators of extinction risk when considered alongside threats to the species, and are firmly founded in conservation biology. We assessed the ways in which these demographic characteristics contribute to the species' vulnerability to extinction given the current threats, and those in the foreseeable future. This approach has been successful in assessing extinction risk for a number of species listed under the ESA. The demographic risk criteria were evaluated based on the species' present status in the context of historical

information, if available, and threats that might alter the determination of the species' overall level of extinction risk. These characteristics are critical considerations in evaluating a species' extinction risk and were analyzed using the standard of best available science as required by the ESA.

Where sufficient information was available, we rated all demographic factors and threats as very low, low, moderate, or high based on their likelihood to contribute to the Taiwanese humpback dolphin's risk of extinction. If there was insufficient data available to assess a particular threat, we rated it as "unknown"; the determination of risk relied upon the most current literature and best scientific understanding of the species' status and threat impact. We first considered each demographic factor and threat separately. However, evaluating demographic factors and threats separately may underestimate the synergy and interaction among them. Therefore, demographic factors and threats were also evaluated holistically to determine the overall likelihood of extinction now, and in the foreseeable future.

The definitions of each risk rating are as follows:

(1) **Very low** - it is very unlikely that the particular factor contributes significantly to the risk of extinction;
(2) **Low** - it is unlikely that the particular factor contributes significantly to the risk of extinction;
(3) **Moderate** - it is likely that the particular factor contributes significantly to the risk of extinction; and,
(4) **High** - it is highly likely that the particular factor contributes significantly to the risk of extinction.

(Note: the term "significantly" is used here as it is generally defined – i.e., in a sufficiently great or important way as to be worthy of attention.)

Guided by the results from the demographics risk analyses as well as the threats assessment, we then used our informed professional judgment to make an overall extinction risk determination for the Taiwanese humpback dolphin. For this analysis, we defined three levels of extinction risk:

(1) = **Low risk**: A species is at low risk of extinction if it is not at moderate or high level of extinction risk (see "Moderate risk" and "High risk" definitions below). A species may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species or DPS at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

(2) = **Moderate risk**: A species is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "High risk"). A species or DPS may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The

appropriate time horizon for evaluating whether a species or DPS is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors.

(3) = **High risk**: A species with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species at such a high level of risk may be strongly influenced by stochastic or depensatory processes. Similarly, a species may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create present and substantial demographic risks.

At no point in this analysis was an explicit recommendation made to list the species as endangered, threatened, or not warranted. Rather, we made scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species' demographic risks and assessment of threats.

Demographic Risk Assessment

Abundance

We identified the low population abundance of the Taiwanese humpback dolphin as the demographic factor contributing most heavily to its risk of extinction. With fewer than 100 individuals, lower than the presumed historical population size (based on estimates of carrying capacity and suitable habitat) and projected to be falling, even a single mortality event will impact the population's continued viability. For example, current annual mortality is estimated at 1.5% (Wang *et al.,* 2012). The current rate of PBR is over 7 times faster than the estimated sustainable removal rate of one individual every 7 to 7.6 years. (Slooten *et al.,* 2013). Population viability analyses, which model future scenarios taking into account increasing threats of fishing and habitat loss, confirm the unsustainable decline of the population (Araújo *et al.,* 2014; Huang and Karczmarski 2014; Huang *et al.,* 2014). In fact, both assessments agree that the subspecies is in serious danger of going extinct in the near future (Wang *et al*., 2016). It should be noted that reproductive parameters adopted in the PVA studies were primarily species generic to the Indo-Pacific humpback dolphin as a whole, rather than population-specific to the Taiwanese humpback dolphin; therefore, given the dolphin's annual recruitment may actually be lower than current mortality figures (Chang *et al*., 2016), population viability may be at greater risk than previously thought. Overall, the small and declining population size of the Taiwanese humpback dolphin contributes to a high risk of extinction, which is compounded by a variety of ongoing threats to the population and its habitat.

Growth rate/productivity

The Taiwanese humpback dolphin is associated with a slow rate of reproduction, long calving intervals, low recruitment rates and a long period of female-calf association. A recent study on the reproductive parameters of the Taiwanese humpback dolphin indicate low calf survival rate and fecundity (Chang *et al.,* 2016). For the Taiwanese humpback dolphin, low fecundity is likely

caused by current threats of habitat contamination, stress, and prey disruption. With reduced population size, the low reproductive rate and fecundity of the subspecies most likely impedes a sustainable growth rate in the face of other threats, and thus contributes to a high risk of extinction. Potential biological removal is expected to exceed the sustainable recovery rate for the Taiwanese humpback dolphin population (Slooten *et al.,* 2013) and exposure to pollution and stress derived from interactions with anthropogenic activity are likely to further reduce reproductive rates of this population in the future. Therefore, the dolphin may continue to experience ongoing trends decreasing reproductive rates, which are likely to prevent the population's adaptability to stress and impede its recovery, even if mitigation efforts are made to address other threats such as bycatch and habitat destruction. Overall, the Taiwanese humpback dolphin's reproductive rate may decrease over time without efforts to mitigate habitat contamination and stress due to anthropogenic activity occurring throughout the dolphin's range. For the Taiwanese humpback dolphin population, a low rate of reproduction and fecundity now, and likely reductions in those rates in the future because of ongoing threats, contributes to a high risk of extinction.

Spatial structure/connectivity

No genetic data exist for the Taiwanese humpback dolphin; therefore, the genetic connectivity within the population cannot be directly assessed. In such a small population, however, social behavior and habitat connectivity may provide clues to the connectivity of the population as a whole. For the Taiwanese humpback dolphin, habitat includes a very narrow strip of near shore waters. Analysis of social behavior of the population has revealed significant and high levels of interconnectedness and gregarious behavior across this habitat range (Dungan 2011; Dungan *et al.,* 2016). As discussed previously, the population is not subdivided into smaller social groups, as is the case for larger mainland Chinese populations (Dungan 2011). Rather, the Taiwanese humpback dolphin exhibits high social cohesion relating to their strong population isolation, low abundance, confined geographic distribution, and anthropogenic stressors that have diminished the productivity of Taiwan's west coast over the last ~60 years (Dungan *et al*., 2016; Dungan 2011). As such, their social structure may be comparably unusual in that these dolphins appear to be utilizing stronger, longer-lasting relationships in order to cope with these environmental and demographic differences (Dungan *et al*., 2016). As previously discussed, the high social cohesion observed in the Taiwanese humpback dolphin is most likely related to cooperative calf rearing; this behavior is thought to be an adaptive response to the dolphin's degraded, geographically restricted environment (which makes it difficult for mothers to support offspring on their own), and to their small population size (which has likely increased the relatedness of individuals) (Dungan 2011). The interaction between behavior, genes, adaptation, and environmental selection has been widely discussed in sociobiological theory, and addresses those genes involved in conspecific recognition and interaction that may evolve over time and be reflected in differences in social structure and behavior among populations (Tinbergen 1963; Hinde 1976). As such, differences in Taiwanese humpback dolphin social behavior (such as increased incidence of cooperative calf rearing and greater social cohesion) are thought to be of adaptive significance, possibly relating to the modification of hormonal genes controlling for olfactory cues of mother-calf bonding (Broad *et al.,* 2006; Dungan 2011). However, more data are needed to reject the null hypothesis that high social cohesion

exhibited by the population is simply a facultative response to population density and size, and not representative of genetic adaptation.

The social structure of this small population may be disrupted by several factors. For instance, damming of freshwater input or construction and land reclamation preventing the transit of individuals across its near shore range may lead to genetic and social fragmentation. Currently, the direct impact of habitat alteration on the genetic and social connectivity of the Taiwanese humpback dolphin is based on limited data. Disruption of social structure through mortality or habitat fragmentation may hinder the transference of information and destabilize the community structure that aids in the adaptability of the small population in the future. Current threats to habitat, fishing entanglement, and direct mortality continue to increase, and may disrupt the social stability and physical connectivity among individuals within the population, particularly through the deaths of breeding females. However, the extent to which these effects directly impact the connectivity of the small and isolated population remains uncertain. Based on the narrow habitat range and isolated nature of the population, with high within-population connectivity, continued alteration and fragmentation of this connectivity due to increasingly constricted habitat may hinder their future ability to adapt to threats, and contributes moderately to the subspecies' risk of extinction.

Diversity

While data do not exist to address the genetic diversity of the Taiwanese humpback dolphin population, there are several reasons to believe that diversity is reduced in the population. First, with possibly fewer than 75 individuals in the reproductively isolated population (which is well below the minimum population size (i.e., at least 250 individuals) required for marine mammals to resist stochastic genetic diversity loss), the gene pool may be experiencing critical bottlenecks. Next, social structure is highly connected in the population. This suggests that genetic substructure within the population does not exist, and diversification within the population is not supported by current environmental or behavioral mechanisms. Low diversity may contribute to low physiological flexibility for the population to adapt to changes in the marine environment projected in future climate scenarios. The combination of low diversity and small population size most likely increases the population's vulnerability to current and increasing threats. Insufficient data are available to directly determine the effect of small population size on the genetic diversity of the population. However, although insufficient data are available, evidence from abundance and social structure suggest that diversity is likely low, and may contribute moderately to the extinction risk of the subspecies.

Threats Assessment

Based on the above analysis of ESA factors and threats, the current risk to the survival of the species was considered, as well as whether each threat will increase or decrease into the foreseeable future. Here, we determined foreseeable future as the time frame over which the threat can be projected with a reasonable amount of confidence. For the most part, foreseeable future is stated qualitatively, in terms of the projected trend of each threat.

It is highly likely that destruction, modification, and curtailment of habitat and range poses a significant threat to the Taiwanese humpback dolphin's likelihood of extinction. Widespread industrial, municipal, agricultural, and residential development has resulted in extensive land reclamation, pollution, and freshwater diversion, all which degrade and eliminate natural estuarine habitat of the Taiwanese humpback dolphin. Habitat fragmentation because of these activities also has serious implications for the subspecies, particularly due to the cohesive nature of the population and reliance on undisturbed dynamics of mother-calf groups. These activities have exhibited increasing trends over the past several decades, with little indication that these activities will cease in the foreseeable future. Thus, the impacts of these threats on the Taiwanese humpback will likely continue and may intensify in the foreseeable future. We determined that destruction, modification, and curtailment of habitat in the form of coastal development and freshwater diversion contribute a high likelihood of risk to the continued existence of the Taiwanese humpback dolphin. We are confident that this risk will be exacerbated in the foreseeable future. Pollution and contamination of habitat likely impact the continued viability of the population by reducing fecundity and immune health. We determined that habitat pollution contributes a moderate risk to the dolphin's likelihood of extinction. This risk may increase in the foreseeable future, as pollution discharge into the dolphin's habitat is largely unchecked.

We determined that overutilization for commercial, recreational, scientific, or educational purposes in the form of whale watching and scientific monitoring are unlikely to contribute significantly to the extinction risk of the Taiwanese humpback dolphin now, or in the foreseeable future. However, we acknowledge that while these activities may cause relatively lower levels of stress on their own, they can act synergistically with other more prominent threats.

While it is possible that increased human activity and climate change may increase the dolphin's exposure to new and invasive parasites or disease, there is currently a lack of data to determine with confidence whether disease and predation are factors that contribute significantly to the extinction risk of the Taiwanese humpback dolphin, now or in the foreseeable future.

It is likely that the inadequacy of existing regulatory mechanisms, particularly due to lack of enforcement, contributes to a high risk of extinction for the Taiwanese humpback dolphin. While some regulations are in place, such as banning of DDT, CITES trade restrictions, and a Taiwanese Wildlife Conservation Act listing, these regulations are either not adequately enforced, or do not address the primary threats to the population. Regulations in the future will need to address habitat destruction, bycatch, pollution, and fishing interactions in order to adequately protect the species from threats and prevent further population declines. Further, adequate enforcement of current regulations is necessary to ensure effectiveness.

Interaction with fisheries (e.g., incidental bycatch and entanglement), climate change, acoustic disturbance, and vessel strikes are other natural or manmade factors affecting the continued existence of the Taiwanese humpback dolphin. Bycatch, entanglement, and interaction with

fisheries pose the most immediate and significant threat to the Taiwanese humpback dolphin. As discussed in detail previously, fishing pressure, entanglement, and fishing-related injury and mortality are likely to increase in the future (Ross *et al.,* 2011; Slooten *et al.,* 2013). The effects of climate change on the Taiwanese humpback dolphin habitat and survival are not understood; however, due to the potential for climate change to disrupt food availability for the dolphin, we considered this threat as contributing to a moderate risk of extinction for the dolphin in the foreseeable future. Although acoustic disturbance may disrupt behavior and is likely to increase in the foreseeable future with increased boating and industrial activity within the dolphin's habitat, we determined that acoustic disturbance contributes to a relatively low risk of extinction to the Taiwanese humpback dolphin. Out of all threats within this category, serious injuries and mortality resulting from fisheries interactions, including bycatch and entanglements with fishing gear, pose the highest risk of extinction to the Taiwanese humpback dolphin.

Table 2 Summary of threats organized by ESA Factor and their associated risk likelihood rankings.

ESA Factor	Threat	Risk Likelihood
Habitat	*Development/Land reclamation*	High
	Freshwater Diversion	High
	Contamination/Pollution	Moderate
Overutilization	*Whale Watching*	Low
	Scientific monitoring	Low
Disease/Predation	*Parasites*	Unknown
	Shark Predation	Unknown
Inadequacy of existing regulatory mechanisms	*Lack of enforcement, implementation, or effectiveness*	High
Other	*Bycatch and entanglement*	High
	Vessel strikes	High
	Acoustic disturbance	Moderate
	Climate Change	Moderate

Overall Extinction Risk

We identified several threats that likely affect the continued survival of the Taiwanese humpback dolphin, including destruction, modification, and curtailment of its habitat (e.g., land reclamation, industrial, agricultural, and municipal pollution, and river diversion), bycatch and entanglement in fishing gear, and acoustic disturbance. Of these threats, destruction and modification of habitat through river flow diversion, pollution, and land reclamation, as well as entanglement and bycatch pose the highest risk of extinction for the Taiwanese humpback

dolphin. These threats are immediate, and intensity of these threats is likely to increase in the future. Regulations to mitigate these threats are not currently in place, and plans for mitigation have not yet been implemented. Analysis of demographic factors identified several characteristics that elevate the population's vulnerability to these threats. For example, heavily diminished and declining population size drastically elevates the impact of even a single mortality event. Evidence suggests that diversity of the population is low, which reduces the resiliency of the population to threats and changes in its habitat. The population appears to be cohesive, most likely due to low population size and the narrow extent of its habitat. The potential for future disruption of social structure due to habitat fragmentation may heavily impact the transfer of generational information, calf survival, and foraging success. Finally, the population exhibits naturally low rates of reproduction and productivity, and data suggest that stress and habitat pollution act to further reduce the population's fecundity and productivity. Given these demographic characteristics, the aforementioned threats work synergistically to disrupt social structure, increase stress, limit food availability, and reduce fecundity while resulting in direct loss through mortality, injury, and prevention of population recovery. Due to the immediacy and intensity of threats, and demographic characteristics increasing the vulnerability of the population, we have concluded that the Taiwanese humpback dolphin has an overall high risk of extinction.

CONSERVATION EFFORTS

The IUCN has listed the Taiwanese humpback dolphin population as Critically Endangered based on current threats and depleted population size that is continuing to decline. The IUCN listing does not result in regulations or directly implement conservation or species management. Instead, the goal of the IUCN Red List of Threated Species is to provide information and analyses on the status, trends, and threats to species in order to inform and catalyze action for biodiversity conservation. Since the Taiwanese humpback dolphin population was listed on the IUCN Red List in 2008, no formal management measures for its protection or conservation have been applied.

Non-governmental organizations (NGOs), scientists, activists and residents of Taiwan have invested significant amounts of time and resources into the conservation of the Taiwanese humpback dolphin (Wang *et al.,* 2016). For example, a series of scientific workshops have been conducted to discuss the conservation of the Taiwanese humpback dolphin population. These took place in 2004, 2007, 2011 and 2014 (and with two more planned to be held in 2017), bringing together scientists, policy makers, and international partners to discuss conservation options for the species. The first and second workshops in 2004 and 2007 focused on the conservation and research needs of this subspecies (Wang *et al.,* 2004a; 2007a). These workshops brought together international and Taiwanese science, education, conservation, and policy representatives to outline threats and develop priorities for conservation and research. The overarching goals of each workshop were to define the conservation status, current threats, and outline potential conservation measures that would best assist the recovery of the subspecies. Since these workshops, research on the population has increased greatly, and

understanding of the subspecies' abundance and population trends have improved. However, actions have yet to be taken by the local government to reduce any of the major existing threats faced by the subspecies (Wang *et al*., 2016). Therefore, overall, we could not find any additional conservation efforts that would reduce the extinction risk of the Taiwanese humpback dolphin.

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