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*A review of the impacts of anthropogenic activities on the critically endangered eastern Taiwan Strait Indo-Pacific humpback dolphins (*Sousa chinensis*)*

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Abstract

Small cetaceans are increasingly being recognized as high risk groups subject to multiple human threats that can act synergistically on vulnerable populations. The eastern Taiwan Strait (ETS) population of Indo-Pacific humpback dolphins, Sousa chinensis, is dependent on the estuarine systems of Taiwan's west coast, and so has habitat that overlaps greatly with human activities. With fewer than 100 individuals, the population has a *Critically Endangered* status on the IUCN Red List. Threats to the population include habitat loss, noise and disturbance, fisheries interactions, chemical pollution, and reduced freshwater outflow to estuarine ecosystems. Evaluating each threat separately underestimates synergistic effects among them, and if the population is to remain viable in the long-term, most of these threats will require mitigation. We emphasize that the immediate protection of priority habitat, which has already been described in detail for this population, offers perhaps the best strategy for legally binding broad-scale threat reduction. Continuing research on this population highlights both its dire status and ecological uniqueness. If the ETS humpback dolphins are successfully conserved, their case may become a practical and inspirational model for the protection of many other vulnerable marine organisms. [JMATE. 2011;4(2):3-9]

Keywords: Sousa chinensis, *cumulative threats, priority habitat, population viability*

Introduction

Cetacean conservation is, relatively speaking, still in its infancy. The establishment of the International Whaling Commission (IWC) in 1946 was a response to declining stocks of commercially hunted species, but serious cetacean conservation for reasons other than harvest management was minimal prior to the 1970s (3). Since the moratorium on commercial whaling was put in effect in 1986, several species that were once heavily hunted have been recovering (7), but the focus of cetacean conservation has traditionally only been on the mysticetes and sperm whale. There is currently no international body responsible for the conservation of small cetaceans (by far the most diverse group of marine mammals), which today include some of the most endangered species and populations in the Order.

Small cetaceans are increasingly being recognized as high-risk groups. For example, now that the baiji (Lipotes vexillifer) is almost certainly extinct (27), the vaquita (Phocoena sinus) is today arguably the most endangered cetacean species, primarily due to incidental catches in fishing nets (9). As global ocean issues (overfishing, climate change, contamination, acidification, etc.) are repeatedly raised in environmental policy, it is becoming clear that the impacts of human activities on cetacean populations are complex and due to multiple causes and not just fisheries interactions. Furthermore, these anthropogenic threats are further complicated by the probability of cumulative impacts on vulnerable populations.

Freshwater-dependent cetacean species are particularly vulnerable because they tend to occur in isolation from other populations, and their proximity to human societies usually means they experience more anthropogenic stressors (18). The Indo-Pacific humpback dolphin, Sousa chinensis (Figure 1), is such a species, found in tropical and subtropical near-shore waters around the rim of the Indian and western Pacific oceans (12), with apparently higher concentrations in and around estuaries (21). The species likely consists of over 10,000 mature individuals and is classified as *Near Threatened* by the IUCN Red List of Threatened Species because habitat degradation and bycatch mortality have resulted in a likely decline in abundance over the last 60 years (16).

Despite the low risk status for the species globally, the taxonomy of the genus, Sousa, is unresolved and Sousa chinensis may consist of at least two putative species (6). Given this taxonomic uncertainty, and inferred population declines over most of the species' range, the *Near Threatened* status may in fact be deceivingly optimistic (16). Because populations among species can be isolated, it is often more practical and sensible from a conservation

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Figure 1 - Sousa chinensis *(5) are pink in adulthood with varying amounts of dark grey spotting. Shown here is a member of the eastern Taiwan Strait (ETS) population. Reproduced with permission FormosaCetus*

perspective to consider them as separate risk units for management (1). Currently, only one *S. chinensis* population, that of the eastern Taiwan Strait (ETS), has been assessed as a separate population (17, 31).

The ETS population is one of two for which current research interest is high in Chinese waters, the other being in the Pearl River Estuary (PRE) near Hong Kong (10). Sousa chinensis has not been observed in offshore waters deeper than 30 m (11) so the Taiwan Strait appears to be an effective barrier to the movement of dolphins between the west coast of Taiwan and the coastal waters of mainland China. Even though molecular data are currently unavailable, clear pigmentation differences displayed by the ETS population indicate likely genetic isolation (28). The abundance of the ETS Sousa chinensis was estimated to be fewer than 100 individuals (30), which in combination with human impacts makes population decline likely and resulted in a *Critically Endangered* status on the IUCN Red List (17) under criterion C2a(ii). This criterion includes: population numbers fewer than 250 mature individuals, a continuing decline is reasonably inferred, and at least 90% of mature individuals occur in one subpopulation. Additionally, because 50%-60% of the ETS population are likely mature individuals (10), it may also qualify for *Critically Endangered* status under criterion D with an abundance of fewer than 50 mature individuals (8). With the wide variety and increasing intensity of human activities in the dolphins' habitat, a continuing decline in the dolphins' abundance can be inferred.

Discussion

Summary of population threats

The threats to the ETS humpback dolphin population fall into five categories: the reduction of freshwater outflow, underwater noise, habitat loss, fisheries interactions, and contamination from industrial, municipal and agricultural discharge. These threats were identified as of most concern to the ETS population by an international group of experts (32).

Noise and disturbance from ship/boat traffic, military exercises, seismic research and near-shore percussive pile driving may be having a negative effect on the population (25). The ETS humpback dolphins are subject to chronic noise exposure from dense fishing boat activity and commercial and industrial shipping in their habitat. In bottlenose dolphins and beluga, this kind of persistent disturbance has been shown to cause temporary hearing loss that can become permanent over the long-term (26). In these species, stress hormone levels have also been shown to increase in response to noise disturbances, which can contribute to reduced immune response if sustained (20). Increasing seismic survey activities are also a threat to the ETS humpback dolphins. In 2009 the Lamont-Doherty Earth Observatory (L-DEO) proposed a seismic survey with a track route that would have taken the survey vessel to approximately 1 km off Taiwan's west coast, which was directly within dolphin habitat. Only after numerous critical comments by marine mammal scientists and other concerned parties were the survey plans revised to divert survey tracks to 20 km offshore of western Taiwan (14).

The reduction of freshwater outflow and the degradation of estuary and coastal habitat is also a threat to this coastal dolphin population (17). Dams, flood control and other river alterations used to facilitate industrial, agricultural and municipal needs all affect freshwater input to estuaries. Jefferson described the importance of estuarine habitat to the PRE population of humpback dolphins near Hong Kong (10), and the ETS population also appears to rely on this type of ecosystem. Numerous sightings of individuals from the ETS population in estuarine waters support the

importance of preventing further reductions in freshwater flow to Taiwan's west coast (30), where the flow of all major river systems to estuaries has already been severely reduced.

While changes in freshwater output alter estuarine systems, there are many other factors causing direct losses of ETS humpback dolphin habitat. These include land reclamation, break-walls, and dredging (32). The central western coast of Taiwan is already heavily industrialized (factories, chemical plants, industrial ports, etc.), but proposals for the expansion of existing facilities via coastal land reclamation still continue (31, 32). Recently, for example, there was a proposal for a 4000 hectare land reclamation project for a petrochemical facility that would have been located directly in the centre of ETS humpback dolphin habitat (29). This project was halted (in part due to heavy public lobbying to conserve the dolphins), but because there is no legal protection for the proposed site, other projects, including a reconsideration of this one, may be proposed in future.

There are over 600 factories located within a kilometer of the shore on the western coast of Taiwan, all of which contribute to the substantial amount of pollution in the area (32). Industrial, agricultural and residential discharge with minimal to no treatment pose an immediate threat to the humpback dolphins through direct exposure, but of greater concern is the ingestion of contaminated prey (15, 25). Small cetaceans, as long-lived, top predators in marine ecosystems, can be exposed to high levels of persistent environmental contaminants through bioaccumulation and biomagnification, often with negative consequences for immune response and reproductive health (22). Biopsied humpback dolphins from the PRE population showed levels of polychlorinated biphenyls (PCBs) and DDT that surpassed effects thresholds for marine mammals (15), which suggests the same may also be true for the ETS population given they both occupy waters adjacent to heavily urbanized and industrialized areas (25).

Fisheries interactions (bycatch and boat collisions) are perhaps the most serious direct threat to the ETS humpback dolphin population (17, 32), with gillnets and trammel nets being the two gear types that pose the greatest threat to individual dolphins (25). Thousands of these nets are set in the coastal waters of-western Taiwan (17, 31), and their likely impact on the population is substantiated by the extensive scarring of individuals – over 30% of known individuals possess scars that were most likely caused by interactions with fisheries (Figure 2) (32). The injuries sustained by the individuals, if not always lethal, may contribute to mortality in combination with other factors, such as a weakened physical condition from toxic immunosuppression, noise stress, or malnutrition. For example, observations of a recent stranded individual suggested net entanglement contributed to its cause of death, but it also appeared emaciated (J. Y. Wang, pers. comm.).

Figure 2 - An individual from the ETS population with a net roping around its body. Reproduced with permission of Pedro Fruet.

With fewer than 100 individuals in an isolated population, the removal of even a single individual per year substantially reduces intrinsic population growth rate. Each of the anthropogenic threats identified for this population can adversely affect the population in their own right, but it is their cumulative (and likely synergistic) effects that ultimately translate into the conditions experienced by individual dolphins. As such, evaluating each threat separately will likely underestimate the potential for interactions among them. The *Critically Endangered* status of the ETS humpback dolphins is due to multiple human-caused threats, and if the population is to remain viable in the long-term, most of those threats will likely require mitigation to reduce their impacts. The effective protection of priority habitat requires the mitigation of diverse impacts by proxy, so the designation of priority habitat is an important step in achieving broad-scale threat reduction.

The importance of priority habitat designation

In 2009 a group of international marine mammal experts gathered to evaluate all available evidence for determining the confirmed and suitable habitats of the ETS humpback dolphin population. Based on current and historical sightings, stranding records, and on published preferred habitat types for the species, priority habitat was described for the ETS population. Priority habitat was defined as encompassing all habitat that is required for a distinct population or species to ensure it is sustained for the foreseeable future (23). This means additional habitat must also be considered in the context of any potential large-scale disasters. For example, confirmed ETS humpback dolphin habitat lies within areas of high commercial shipping traffic so the potential for an oil spill is higher than in areas with low traffic. As priority habitat is being delineated, scientists and policy-makers must determine if it is sufficiently large to sustain the population or species in such instances.

The confirmed habitat of the ETS humpback dolphins falls along the coastline of western Taiwan from Long-Fung Harbour in Miaoli County (24°41'N, 120°51'E) south to Jiangjyun fishing port in Tainan county (23°12'N, 120°05'E), generally in waters less than 30 m (2, 28, 30). To accommodate the potential for additional habitat requirements, priority habitat was classified using the ten guiding principles for small cetaceans set forward in Ross et al. (23). For the ETS humpback dolphins, it was argued that priority habitat must include both the confirmed habitat of the population and adjacent suitable habitat, currently unoccupied, to accommodate the recovery and sustainability of the population (25). This would presumably allow habitat requirements (i.e. sufficient quantity and quality of food) to be met while also incorporating the precautionary principle to account for unknown, unanticipated, and/or cumulative effects. This more precautionary approach to defining priority habitat for the ETS population also offers a better chance of recovery in the presence of scientific uncertainty (23).

Aside from habitat that has been confirmed, sightings and strandings further north and south of this range provide additional evidence that the population's historical habitat usage stretches further than what has been so far observed in dedicated surveys. Habitat deemed suitable based on physical and biological features also influenced priority habitat designation (Fig. 3). Offshore habitat margins for the ETS humpback dolphins were defined by depth and distance from shore. Priority habitat was designated as lying within the 30 m bathymetric line relative to dry land at the lowest low tide, and within 3 km of shore - whichever criterion resulted in a more distant offshore margin (25). As more information becomes available such as updates to ranging patterns, habitat requirements, and additional threats, priority habitat should be subsequently reconsidered to allow for adaptive management. A static declaration of priority habitat could result in a designation too small to sustain the population, and make it susceptible to "edge effects". Specifically, environmental conditions will often change along habitat borders as a function of proximity to neighbouring

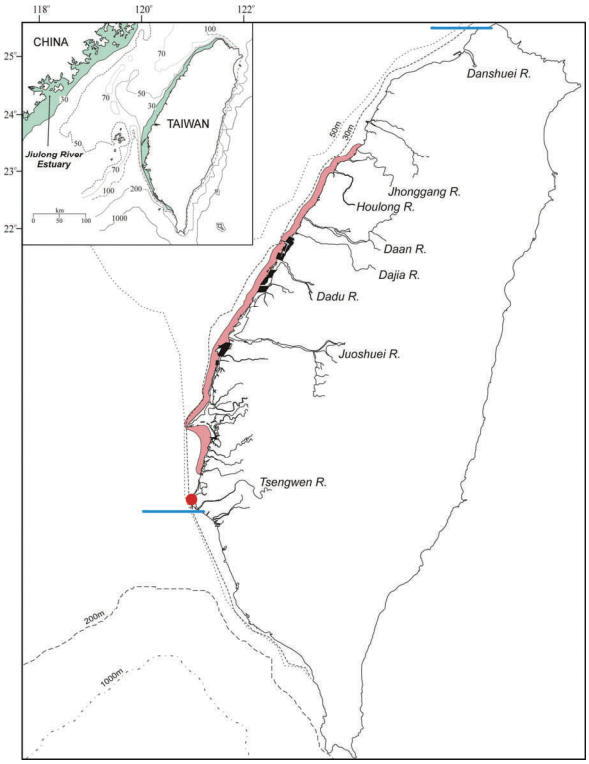

Figure 3 - A map of Taiwan indicating its proximity to mainland China along with the bathymetric features that confine the ETS population to the west coast of Taiwan. The confirmed habitat of the ETS Sousa chinensis *is depicted by the pink shaded area (a single stranding event outside this area is indicated by a red dot). The borders of delineated 'priority habitat' are portrayed by the blue lines north and south of the confirmed range, and green shading in the map inset highlights the area within the 30 m isobath. Black shaded polygons within the confirmed range represent areas of reclaimed land, a major contributor to ETS dolphin habitat loss and degradation.*

environments, and this can decrease habitat quality when adjacent regions are more anthropogenically affected. So, "edge effects" are reduced when protected areas are larger because of a decreased perimeter to area ratio (34).

Although the term "priority habitat" does not possess any legal standing for habitat protection, the guidelines for defining this area can be an important tool for managers and conservationists attempting to designate habitat for legal protection. The sustainability of a population or species depends on the application, compliance and enforcement of legally protected priority habitat (23). The classification of priority habitat for this *Critically Endangered* population has helped to define what is required to reduce further decline in dolphin numbers. However, only if this scientific advice is used to guide the designation of legally protected habitat, and if that protection is enforced, can there be benefits to the dolphins.

Ongoing and future research

While priority habitat designation and protection has been proposed as the most effective immediate action that can be taken, ongoing and future research is becoming increasingly broad in its focus. This trend emphasizes the importance of understanding the population's biology in the context of multiple human impacts.

Research on the potential risks from exposure to other persistent organic pollutants, such as PCBs and DDT, is underway for this population. Because high exposure to environmental toxins can compromise the immune system (13), other threats that impact dolphin health either directly (wounds from fisheries interactions) or indirectly (stress from noise disturbance) may be having more severe effects than they otherwise would. As survey effort accumulates, the spatial distribution of this population is also becoming better understood. An examination of individual ranging patterns indicates a single population of individuals that range widely throughout the known distribution of this population (33). This is supported by recent results from a social network analysis that indicate a cohesive, interconnected population with long-term dyadic relationships. This pattern contrasts with Sousa chinensis in the Pearl River Estuary near Hong Kong, which have comparatively weaker relationships and are organized into two distinct social clusters (4).
In addition to these newer research initiatives, population monitoring is still continuing. Updated mark -recapture estimates (J. Y. Wang, unpublished data), now more precise and accurate with growing data, indicate a considerably lower abundance than previously estimated by Wang et al. (30). Research priorities for the near future include: developing non-invasive methods of determining individual sex, habitat modeling to gain a better understanding of which environmental factors influence dolphin distribution, acoustical studies to gain insight into noise impacts, and the estimation of demographic parameters to improve viability assessments.

Addressing the cumulative effect of human impacts on the population is a matter of urgency. The precarious state of this population is the result of multiple threats that need to be considered synergistically to appreciate their full effects. There is currently considerable data to indicate immediate action is required to conserve the ETS humpback dolphins, but this will require efforts on many fronts. A successful conservation strategy should be based on the precautionary principle, and not be limited by scientific uncertainty (19). The priority habitat classification presented in Ross et al. (25) is currently the most informed scientific conservation advice available for this *Critically Endangered* population of dolphins.

Gone are the days when industrial whaling was the main issue in cetacean conservation. Today, incidental catch, habitat degradation, chemical pollution, and climate change are also dominant issues, and cetacean conservation is near synonymous with aquatic conservation as a whole. The diversity of threats being faced by the ETS humpback dolphins is both an immense challenge and hope, for if overcome, the success of this *Critically Endangered* population's case may well become a practical and inspirational model for conservation efforts for many other at-risk marine organisms.

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