# Potential Mitigation and Monitoring Options for Impacts to *Sousa chinensis*: Proposed Land Reclamation along Taiwan's West Coast[1]

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**Abstract:** A man-made island is proposed for the development of a petrochemical refinery and industrial complex in Changhua County, Taiwan. The reclaimed land will extend across the normal depth range and movement corridor of the critically endangered Eastern Taiwan Straight (ETS) population of *Sousa chinensis*. Potential significant impacts for *S. chinensis* include habitat fragmentation, reduction in prey resources, contamination, acoustic disturbance, and increased vessel strikes. These potential project impacts were reviewed to identify general mitigation measures, their potential effectiveness, and monitoring opportunities that may provide additional information to inform future planning if a decision is made to construct a facility at this site. The level of impact is currently difficult to accurately predict due to the limited information on this population, existing conditions at the site, and proposed construction and pollution control procedures as well as the complex interactions of important variables. This preliminary assessment of potential mitigation technology suggests that it is not sufficient to adequately protect the ETS population and hence, from a conservation perspective, this project should not be built at this site. However, if this project is built, an aggressive adaptive mitigation approach, focused on minimizing significant impacts and monitoring the at-risk population and habitats, is recommended.

Keywords: Indo-Pacific humpback dolphin, impact mitigation, man-made islands, coastal land reclamation, adaptive mitigation, coastal environmental monitoring

## 1.0 Introduction

The creation of an artificial island via the reclamation of a coastal area in Changhua County is proposed to support the development of a petrochemical refinery and industrial complex (Figure 1.1 from Sheehy 2009). If a facility is built at the proposed Changhua site, there will be a number of unavoidable adverse impacts. Anticipated impacts identified in a scoping review (Sheehy 2009) include habitat fragmentation, reduction in prey resources, contamination, acoustic disturbance, and increased vessel strikes (Figure 1.2 from Sheehy, 2009). To help assure the preservation of the ETS population, the facility should not be built at this site or anywhere else within the limited ETS population habitat. The highly vulnerable status of the ETS *S. chinensis* population justifies a precautionary approach to ensure that this project does not become the tipping point for the extirpation of this endangered population.

[1] The second in a series of three reports on the ETS population of *Sousa chinensis*
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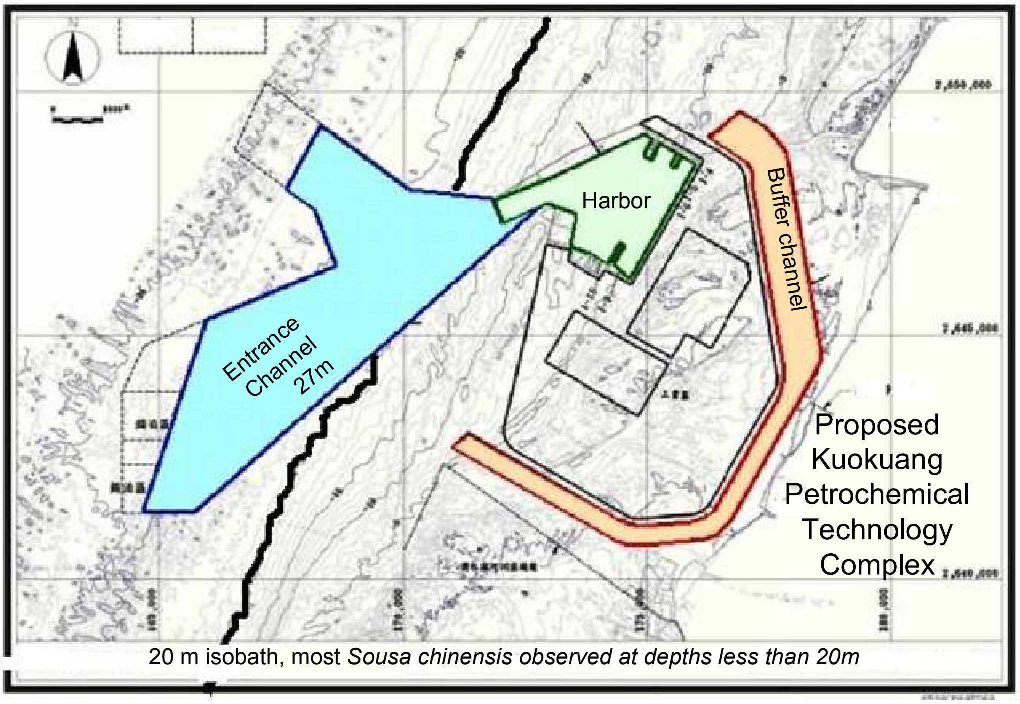


Figure 1.1. The proposed petrochemical facility layout illustrating that the facility will extend across the normal depth range of *Sousa chinensis* (to the 20m isobath).

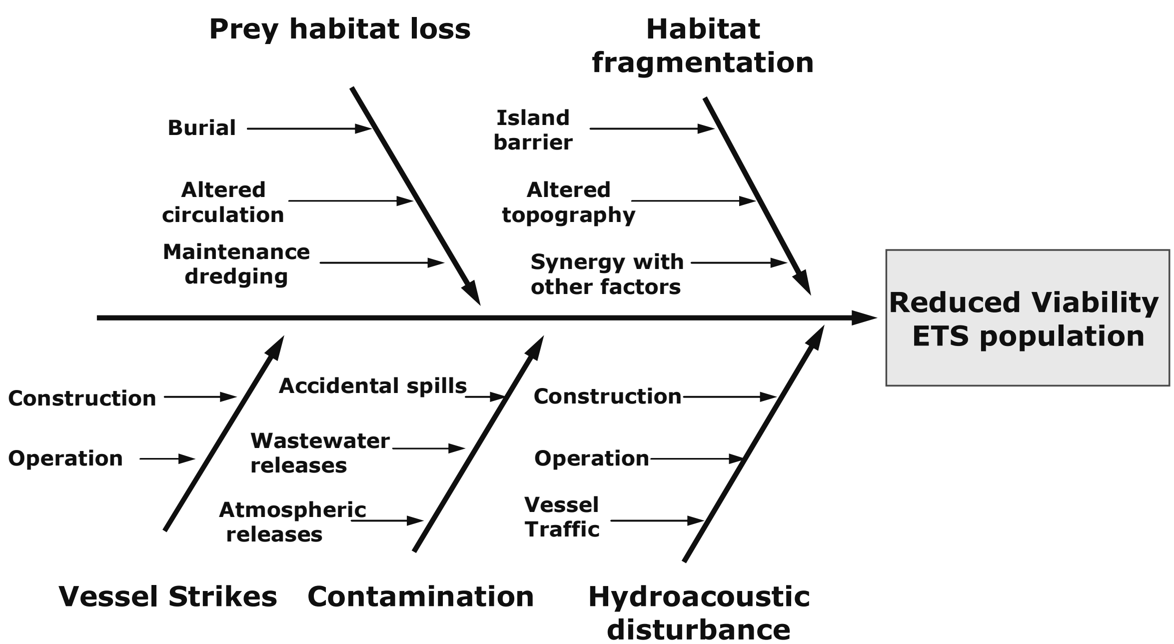


Figure 1.2 Cause and effect diagram for five potential types of adverse impacts to the ETS population of *S. chinensis* from the proposed Changhua County land reclamation project

Due to the small size of the ETS population, all five risk factors identified in the scoping review (Sheehy 2009) may individually result in significant adverse impacts. Since the project impact on the population is the joint consequence of all these, and perhaps additional factors, the cumulative impact presents a high risk of population extirpation. Although some factors can be partially mitigated, they cannot be eliminated. For example, sound disturbance, vessel strikes, and the probability of a catastrophic spill may be reduced to some extent by applying appropriate mitigation measures. However, the level of reduction in magnitude or probability of impact is uncertain as are the joint consequences of the multiple risk factors. It may also be possible to reduce the impact on prey species by restricting fishing and enhancing habitat, but this is uncertain, due to site conditions and untested technology. Habitat and/or population fragmentation, if it occurs, may be the most significant long-term impact and one for which mitigation is not likely to be adequate. However, should this project proceed for short-term economic purposes despite significant environmental impacts, there is a critical need to monitor the actual impacts and implement the best available adaptive mitigation measures to address predicted and unforeseen impacts. The objective of this report is to identify potential mitigation and monitoring options available should this facility be built.

## 2.0 Potential Mitigation

Environmental assessments are decision support tools and don't always preclude a decision that has adverse environmental consequences. Some potential mitigation measures are briefly identified here as a contingency, should this project be approved. Mitigation planning is focused on reducing the exposure of *S. chinensis* to project environmental impacts in terms of their magnitude, frequency, or duration (Sheehy 2009a).

The impact assessment and mitigation planning process is often a one-time event that is highly dependent on the accuracy of predicted impacts and projected mitigation performance. Due to uncertainties about the status of the ETS population, prior cumulative impacts, the synergistic impacts of this project, and the limitations of mitigation state-of-the-art, there is no assurance that long-term impacts can be accurately predicted or that proposed project mitigation will prevent significant adverse impacts to the ETS population. Particularly when baseline information is lacking and innovative mitigation methods are proposed, ex ante predictions of impacts or the performance of proposed mitigation are uncertain.

Should this project be implemented, a more systematic and well planned approach that mandates monitoring and allows for adaptive mitigation (Figure 2.1) based on monitoring results will be essential to providing a means of addressing critical impacts (sensu Karkkainen 2002). Adaptive mitigation management is systematic approach for improving environmental management and building knowledge by learning from initial outcomes. As a result, the final scope, feasibility, and life-cycle cost of meaningful mitigation is impossible to estimate at this time. However, based upon anticipated impacts (Sheehy 2009) some conceptual mitigation approaches can be identified. Some of these methods may also have restoration applications elsewhere in the ETS population range.

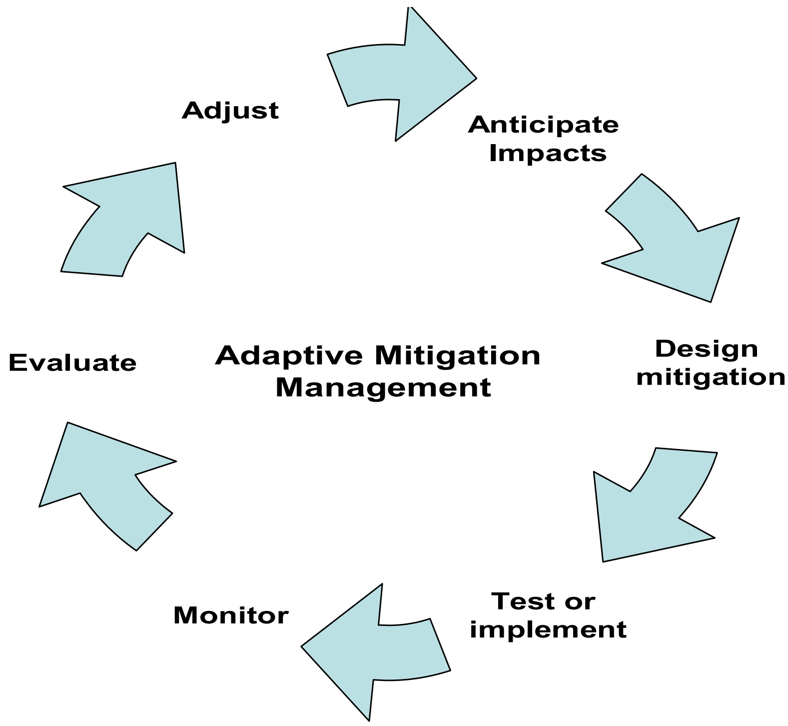


Figure 2.1. If the project is implemented, adaptive mitigation management is needed to address uncertainty with respect to project impacts and the performance of potential mitigation measures.

Based on impacts anticipated at this time (Sheehy 2009), the initial mitigation objectives for *S. chinensis* include:

1. Increase prey fish abundance and/or availability
2. Promote dolphin movement around the reclaimed island
3. Reduce and control adverse underwater sound propagation
4. Prevent, minimize, and effectively contain contamination releases
5. Reduce vessel collisions (strikes)

If this project is implemented, adequate lead time and effort will be needed to develop a well integrated mitigation and monitoring plan needed for adaptive mitigation management. Mitigation measures identified below are only generally described because further information and data are needed on the proposed construction effort, the project environment, and the current status of the ETS population prior to final selection and tailoring of appropriate methods. Many mitigation measures will be implemented during construction to prevent or reduce the severity of potential impacts. Other adaptive mitigation measures are triggered during operation when implemented monitoring indicates a serious problem.

### 2.1 Mitigating potential loss of prey fish species resources

Although there are a number of ecological functions lost due to burial or degradation of soft bottom habitat, compensatory mitigation for fish prey lost is focused on replacing the production base lost due to land reclamation and related impacts. Developing and scaling mitigation options requires identifying probable prey species, their habitat preferences and food, and how much soft bottom production supporting prey species is lost or degraded.

Options for directly replacing lost habitat and associated prey abundance in-kind are very limited since there are no practical options for recreating additional soft bottom habitat over the long term. Geotextile tubes have been used to alter coastal morphology and create additional shallow habitat, but the changes would be difficult to maintain and their use would have collateral impacts. Some innovative terrace reef structures that have been described (Aquabio 2005 unpublished report), but these have not been tested and, given the scale of loss and local substrate characteristics, make it impractical. As a result, off-site and out-of-kind mitigation will be required. This may be restricted to restoring other habitats, limiting existing fishing, stocking cultured prey, or creating new forms of productive habitat

The utility of restoring other habitats is based on addressing other factors currently limiting prey fish abundance or production including pollution and habitat degradation contributing the dolphin's food web. Since prey fishes are found in nearshore areas, they have also been subject to past habitat loss due to land reclamation and degradation due to pollution. Many of the demersal prey species feed on benthos that, due to the fine sediment composition within the range, may preferentially accumulate contaminants such as PCBs and petroleum (Piérard, et al., 1996). Restoring other elements of the coastal ecosystem that supports *S. chinensis* might in include estuarine restoration such as mangrove or wetland rehabilitation, remediation of contaminated sediment areas (hot spots), and restoring riverine water flow etc. Hsieh et al., (2004) provided an approach for strategic planning to restore wetlands along the west coast of Taiwan. Since the west coast of Taiwan and its estuarine areas have been highly developed and degraded, ample opportunities exist for remediation and compensatory mitigation. However, given the extent of estuarine degradation, this would be a major long-term effort and that would not provide measurable benefits for some time.

A number of the probable prey species are subject to some level of commercial fishing effort that compete for prey stocks available to *S. chinensis*. Reducing fishing pressure on these stocks through the creation and effective management of Marine Protected Areas or via enforcement of regulations may increase availability. It may take some time for prey stocks to recover and compensation for lost catch may be required. Mariculture of some prey species is possible because culture techniques are known for some species and Taiwan is on the forefront of mariculture technology. However, to produce and stock prey in sufficient volume to contribute to the dolphin food web is problematic given the technology and infrastructure development lead time. Land-based culture would complete with other land uses in a region where development is already constrained by water resources and available suitable land. Coastal cage culture might further degrade local habitat where shallow fixed culture gear already limits dolphin habitat. The economics of a culture-based approach would need to be explored, but it would be an expensive and recurring cost option. Redirecting existing culture capacity on a short-term basis during construction might be feasible.

The creation of off-site and out-of-kind habitat enhancement may be the most feasible near-term option. The potential efficacy of this approach is based primarily to *S. chinensis's* opportunistic generalist feeding behavior, limited site fidelity (Karczmarski 1999), and demonstrated flexibility in terms of habitat use. Although the ETS population feeds primarily in the shallow soft bottom habitats near estuaries or ports, other populations use mangrove, rock and coral reef habitats. *S. chinensis* is known to feed at natural reef areas in South Africa and Australia and *S. chinensis* observations in South Africa were highly correlated with the presence of natural and artificial reef habitat. In Algoa Bay shallow rocky reefs provide their primary feeding ground (Karczmarski et al. 2000). The use of coral and fringing reef habitats was also noted in Australia by Parra et al. (2006) and Cockeron et al, (1997). Creating hard substrate by building constructed reefs midwater structures may provide prey species benefits by adding food resources.

Constructed reefs and FADs can increase the local abundance of a number of selected prey species, both demersal and pelagic. Although not necessarily reef residents, many of the potential demersal prey are either reef-associated or can take advantage of the additional food sources provided by reefs. Grunts and croaker are commonly found on reefs all along the US Southeast Atlantic and Gulf of Mexico coasts. Herring, anchovy sardines and mackerel are also common on higher profile reefs and FADs. For a number of species in the Gulf of Mexico, stomach content analysis indicates a clear link to reef communities, particularly Scianidae, Haemulidae, and Sparidae (Sheehy et al. 2007). Leita˜o et al., (2007) indicated that the diet of the sea bream *Diplodus sargus* (Sparidae) was strongly associated with prey availability on constructed reefs suggesting that, due to their enhanced benthic production, these reefs enhance fish stocks. The pelagic prey species are commonly observed on midwater fish attractors and may take advantage of the passive food concentration that occurs with these structures. FADs are used extensively in South Asia for fishing, but also attract cetaceans, which often become bycatch (Dolar 1994). The responses of *S. chinensis* to changes in prey availability are difficult to predict, but its behavioral plasticity with respect to the use of food and habitat resources may enable *S. chinensis* to take advantage of prey using constructed reef and FAD habitat enhancements.

Constructed reefs are increasingly being used for mitigation (Sheehy and Vik, 1984, 1985, 1989) and restoration (Sheehy et al. 1995) applications where habitat loss or degradation occurs due to either planned or accidental impacts to living marine resources. They have also been used to alter the movement of target species or to compensate for forage lost as a result of soft bottom habitat contamination (Sheehy et al. 2003). In this case, constructed reefs would replace soft bottom infaunal prey food with hard substrate epifaunal species and the motile species that reside within the microhabitat created on the reef or FAD surface. A review of past lessons learned will help indentify suitable designs (Sheehy and Mathews, 2006).

Due to the nature of the near-shore coastal region in terms of water depth, substrate characteristics, and local oceanographic conditions, designed and prefabricated reef or attractor modules (Sheehy and Vik 1992) are recommended over natural rock or materials-of-opportunity. Designed structures can incorporate features that improve target species benefits and long-term stability. There are a wide range of constructed reef and midwater attractor designs, but the shallow depth and soft bottom characteristics of the habitat at the proposed site will constrain design options or require some modifications to existing designs to provide long-term mitigation. Several new conceptual designs have been developed for these site conditions (Aquabio 2009 unpublished), but testing would be required to evaluate performance.

### 2.2 Mitigating for a potential barrier to movement

Options for mitigating the potential impact of an effective physical barrier to normal north-south movement are extremely limited due to the extent of geomorphic change and the lack of knowledge concerning how *S. chinensis* will respond to this barrier or how they might respond to mitigation efforts. It is possible that the dolphins will travel around the island and across the relatively narrow channel without significant problems. There are occasional reports of *S. chinensis* in deeper waters (Jefferson and Karczmarski 2001; Ross 2002) and they are occasionally observed out to 30m. However, behavior is difficult to predict without past precedent and an understanding of how the barrier effect of the island may be enhanced by increased sound disturbance and changes in food resources (Figure 2-2). The geomorphic changes that will result from the reclamation are also difficult to predict with accuracy. If this project proceeds, it is vital to conduct some feasibility studies and have contingency plans in place to try to avoid fragmentation of the population.

The constructed island will alter circulation and topography in the surrounding area. Morphodynamic simulation models can help planners predict changes in submarine topography as a result of island and port channel construction Information from model analysis will provide a better understanding of the geomorphic change over time in the vicinity of the island. If a continuous calculation model is used, it will also provide insight as to changes in waves and current flow in the impact area. Coastal morphological changes where monitored for the Yulin reclamation site and the results of the model showed a reasonable comparison to model predictions (Liu et al., 2002). At the Yulin site, most of the changes were at depths less than 10m.

It may be possible to modify the dolphin behavior to induce them to move around the island through deeper water either by attracting them to created concentrations of prey species or using either prey species sounds, conspecific sounds or perhaps in combination of both. Some prey species may be concentrated using constructed reefs or fish attractors, perhaps in a series creating a connected corridor around the island and help predict how dolphins might respond. Underwater speakers might be used to playback prey or dolphin sounds that may induce them to move around the island. Gannon et al. (2005) used playback techniques to demonstrate that the bottlenose dolphins use passive listening to locate prey and orient and move toward broadcast prey sounds. It may even be possible to use acoustic operant conditioning (Taylor et al. 2006) to induce movement around the island. Acoustic Harassment Devices (ADHs) could also be used to prevent dolphins from occupying certain areas. All these concepts are highly speculative and untested. Implementation would require consultation with marine mammal experts and feasibility studies to test their performance.

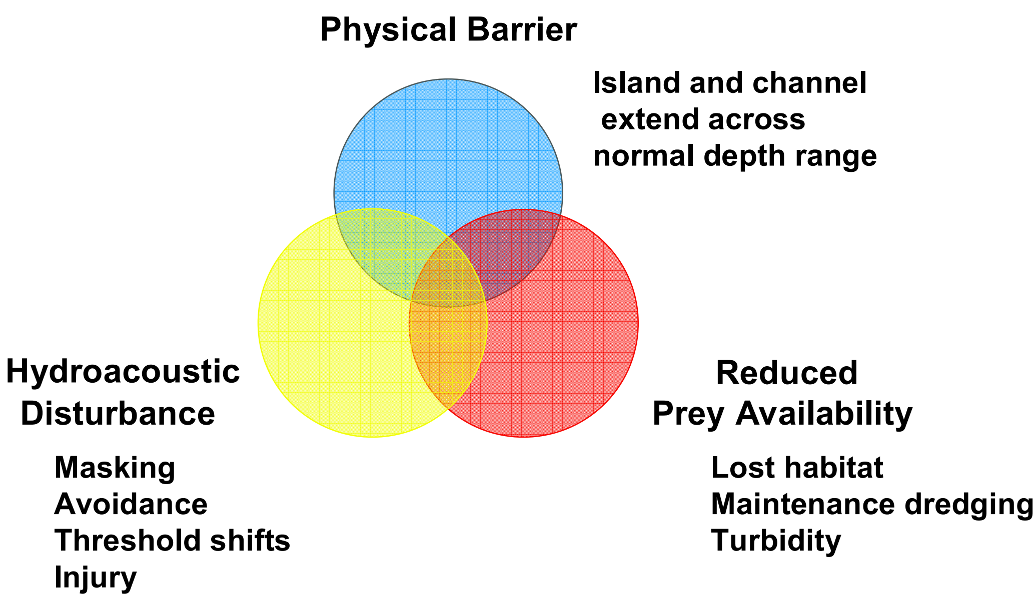


Figure 2-2 Venn diagram illustrating potential synergistic effects may create an effective barrier isolating habitat and potentially fragmenting the ETS population

## 2.3 Mitigating for hydroacoustic disturbance

Mitigation for underwater sound involves selecting the quietest practical construction methods or inherently quiet equipment, incorporating abatement or dampening measures for all significant underwater sound sources, soft start (ramp up) procedures, scheduling activities to avoid critical periods, the use of Acoustic Deterrent Devices (ADDs) and ADHs, and instituting a control process that enables sound reduction or cessation of activity upon observation of dolphins in the primary impact area. Soft start mitigation involves a stepwise progression in sound level intended to enable marine mammals to detect the sound and presumable move away before harmful effects. The efficacy of soft start as a mitigation tool has not really been well tested and it could have negative impacts if the animals are attracted to the initial sound. ADDs or pingers are generally, low amplitude sound sources commonly used to reduce accidental cetacean bycatch in gill nets or other moveable or transient gear. They have been shown to reduce gillnet bycatch of cetaceans species (Barlow and Caneron 2003). AHD's are generally higher power devices placed on permanent structures like dams. Not all cetacean species are equally sensitive to man-made sound disturbance and alarms may need to be adapted for *S. chinensis* (Kastelein et al. 2006). Further work is needed to clarify duration and characteristics of sound sources as well as dolphin and prey fish behavioral responses to the range of amplitudes and frequencies generated by construction and operation sound sources.

Given the project footprint and duration of the construction period, a required monitoring and sound control plan should be required as a condition of any permit. This might include, but not be limited to:

- Measure and evaluate construction generated sound in the project area
- Develop and maintain a monitoring program to estimate the presence of *S. chinensis* in the project footprint and characterize the habitat usage and behavior
- Develop a monitoring program to correlate construction generated sound exposures with *S. chinensis* presence and altered behavior
- Establish and enforce safety procedure to control sound exposure and protect *S. chinensis* in the impact area

Dredging is expected to be a significant long-duration sound source once construction starts. Dredging sound sources include the dredge on-board machinery and power plant, the propulsion engine on the dredge, draghead and submerged slurry pipeline and, if needed, any interim pumping stations. Mitigation suggested includes ship and machinery quieting, reducing propeller cavitations or altering speeds, insulating or elevating slurry pipelines. Mitigation measures also often include exclusionary zones (zones within which the presence of dolphins will result in the shutdown of operation) and avoidance of peak periods of abundance or critical periods. Implementation generally involves qualified and experienced Marine Mammal Observers on board dredging vessels who are responsible for ensuring, through visual observations, that an exclusion zone of 1000m around the vessel is free of marine mammals for 30 minutes before dredging operations commence.

Piling sound generation will depend on the methods used, which may be either percussive or vibropiling. Studies with caged fish suggest that impacts to fish beyond a distance of 400 m may be minimal (Nedwell, et. al., 2003). However, pulsive sounds will likely impact dolphins at a much greater range. Possible mitigation methods include modifications to the piling hammer (reduce height or force, hammer buffers), air bubble curtains, and piling sleeves. Piling hammer modifications extend the impact time; however, this reduces efficiency and may extend the duration of work. Air bubble curtains are used to reduce the propagation of pile driving sound at construction sites (Wursig, et al. 2000) however, performance is not clear (McEwin 2006) especially in deeper water. Under various field conditions (current velocity) they have been problematic and add time to construction. Piling sleeves, which include individual sound barriers around each pile, have been developed (Reyff 2009) and may be the most practical and effective approach. To the extent possible, percussive piling should be eliminated and replaced with vibratory hammers. New methods are being tested, especially for offshore wind power applications, but further research is needed (Slater 2009) to assess their cost-effectiveness.

Vessel sounds arise from a number of sources including the main propulsion machinery, screws and blades (cavitation), on-board and auxiliary machinery (dredging and power generation equipment) and hull flow and slap. Speed is the prime determinant of the radiating noise level, but size and load also have an effect. Each of these can be addressed with some form of mitigation. Selecting and maintaining appropriate vessels, properly mounting machinery (acoustic decoupling), and reducing speed all contribute to reducing vessel noise. Controlling non-essential traffic and reducing the speed for small boats when dolphins are present will also help control sound impacts.

It is not clear whether or not soil compaction contributes significantly to underwater sound. Impacts may depend, in part, on the methods selected and characteristics of the site. Dynamic compaction, vibroflotation, or resonance compaction may have different sound generating properties and selecting methods that minimize sound generation may reduce impacts. Vibroflotation methods may reduce sound production compared to dynamic compaction (Port and Harbor Institute, 1997).

### 2.4 Mitigating contaminant releases and spills

Petrochemical facilities produce a considerable amount of contamination, much of which cannot be mitigated. Controlling or minimizing the release of potential contaminants is both a design and operational issue. State-of-the-art treatment and containment facilities should be included in the design of the facility and all processes. The operation and maintenance of these processes must be closely, continuously, and redundantly monitored and spill contingency plans must be adequate to quickly contain and clean up any accidental releases. Although minor routine or episodic releases, such as from routine offloading, are not as dramatic as a major spill, the consequences, especially for persistent organic compounds or endocrine disrupter chemicals can be significant. A series of recent accidents and fires at the Formosa plastics facility just south in Yunlin indicate that accidental releases may not be rare events.

Major spills are generally characterized as low probability, but high consequence events. As noted earlier (Sheehy 2009), the proposed site may be particularly vulnerable to serous impacts due to the fine grain sediment conditions and the use of heavy crude oil. Therefore it is essential that spill prevention, control, and countermeasure plans for oil be well developed and implementable on short notice to minimize the consequences of accidental release and spill impacts. Spill contingency plans must be based on a realistic analysis and include worst-case scenarios; otherwise they create a dangerous sense of complacency regarding the actual risk of a spill. Plans must be capable of rapid implementation and specify clear lines of authority and responsibility. Hydrodynamic and water and sediment quality models can help predict potential fate and transport for planning spill cleanup actions. Drills and simulations exercises that use available personnel and require the actual deployment of equipment are necessary to determine the adequacy of training, equipment status, and material availability. Contingency plans must be updated regularly to account for changes in operation, equipment status, and governing regulations as well as to obtain feedback from simulation exercises (Sheehy 1989).

### 2.5 Mitigating vessel strikes

Even if not always fatal, vessel strikes can result in injuries that may eventually result in mortality due to secondary causes and affect viability of the individual or social group. Therefore efforts to mitigate potential strikes due to the increase vessel traffic and masking noise associated with construction and operation are important. Mitigation options fall into several categories: restriction, operational measures, or practical measures.

Restrictions might include eliminating unnecessary traffic, reducing vessel speeds, avoiding night or poor visibility conditions, and rerouting around known areas of dolphin concentration. The literature suggests that there is a greater probability of strikes with smaller boats and high speed travel. Speed limits of 6 knots (11.1 km/hr) in zone of potential impact are suggested (Karczmarski 2000). Operational measures would include the use of observers on larger vessels. All vessel operators should be provided with training on avoiding collisions with dolphins. In addition, the regular reporting of dolphin observations (and mandatory reporting of any strikes) may enable scheduling adjustments to reduce the risk of collisions. Practical measures would include the use of passive acoustic detectors which have been used elsewhere to protect cetaceans. For example, in response to a proposed LNG terminal proposal in Massachusetts Bay, the Stellwagen Bank National Marine Sanctuary (US) has recommended that the US Coast Guard and Maritime Administration "require the installation and operation, through the life of the deepwater port, of an array of near-real-time acoustic detection buoys in the Boston Traffic Separation Scheme to reduce the incidence and probability of vessel-whale collisions." A similar approach might be used for the entrance channel to this facility. It may also be possible to develop acoustic warning devices on vessels to alert and displace dolphins. Such a system has been developed and successfully tested for The West Indian manatee (*Trichechus manatus*)[3].

## 3.0 Monitoring and Feasibility Studies

Additional studies are needed to adequately assess the likelihood and severity of potential impacts. If the project is implemented, studies will also be required to monitor actual impacts and the performance of mitigation measures. Active research is ongoing (Chou et al. 2009; Chou 2009), but information on the behavior-ecology and population dynamics of *S. chinensis* in Taiwan waters is still limited.

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[3] Personal communication, Edmund R. Gerstein, Leviathan Legacy Inc. Parametric Projectors Protecting Marine Mammals from Vessel Collisions. 2009 Acoustical Society of America.

Data on prey fish species abundance, benthic production, pollution, and sediment characteristics is essential to predicting impacts and establishing a baseline for measuring environmental changes that may occur. For developing and scaling adequate mitigation, information about prey contamination levels, estuarine utilization, and response to anthropogenic sound are also needed. With respect to sound impacts, further bioacoustical information, such as audiograms, critical auditory bandwidths, reported disturbance levels, spectra of typical vocalizations, and criteria for hearing damage as well as physical oceanography and source sound characteristics, are important (Erbea and Farmer 2000).

If the project is built, monitoring during construction and operation will be required to establish actual impact levels and to evaluate the compliance with mitigation plans and the performance of any implemented mitigation. If necessary, this information will enable planners to adjust mitigation as well as to capture lessons learned during construction and operation. Opportunities for controlled experiments with endangered species are very limited, so information from this large scale habitat manipulation will be useful for future work. Several suggestions for baseline, construction, and post construction monitoring approaches are included.

### 3.1 Evaluating current conditions for impact assessment or scaling mitigation

Further studies on prey abundance and the ecosystem productivity that may be lost in due to soft bottom habitat burial and disturbance are needed to fully assess project impacts. Ideally, field surveys of prey fish abundance and diversity over a minimum of one year are used to estimate of the abundance and diversity of benthic communities impacted by land reclamation. This data is needed to quantify impacts and to scale potential mitigation for prey species. In addition to standard fish trawl and benthic grab surveys, two supplemental approaches are suggested for consideration.

Active acoustic surveys can augment standard fish surveys. Fish abundance has been correlated with mean volume scattering from potential fish prey in the water column for other species of shallow water dolphins. Benoit-Bird et al. (2004) found that when volume scattering, used as an index of prey density, was low, dolphins were rarely present. Although the species and size of potential prey may not yet be related to prey density or energy density, concurrent sonar and fishing surveys may help improve recognition of important prey habitat and provide a less invasive means to measure relative abundance.

Sediment profile imaging systems (Solan et al., 2003) provide a means to conduct a rapid screening assessment of benthic conditions at and surrounding the proposed site. This is an optical technique that can quickly measure and analyze a number of biological, physical, and chemical parameters relative to benthic production over large areas of ocean bottom. It is often used to conduct reconnaissance surveys to develop efficient standard grab or box core sampling designs or to help understand organism-sediment relationships (Rhoads and Germano 1982). It has also been used effectively to help interpret long-term changes in benthic community structure (Rhoads and Germano 1986), assess the impacts of dredged materials disposal on benthic infauna and epifauna (Valente 2006), help monitor the performance of confined disposal sites (Germano 2003), and monitor the benthic and sediment impacts from oil spills (Germano 1995). Since some of the analysis is completed by a computer image analysis system, this provides a more rapid screening approach to help initially assess benthic production impacts resulting from burial, help focus subsequent standard surveys, and monitor post-construction changes.

Stomach content analysis can help establish the linkage between fish prey and their food resources. Prey fish stomach contents studies will help clarify the food web that supports the ETS population. To the extent practical, *S. chinensis* carcasses of opportunity from strandings or fishing gear mortality should also be collected to confirm dolphin prey items and contaminant levels. Opportunities should be maximized by coordinating with local fishing authorities and stranding networks. In addition, other techniques, including stable isotopes (Santos et al. 2007) should be considered for both fish prey and dolphins.

### 3.2 Monitoring impact and mitigation performance

If the project is built as planned, monitoring during construction and operation is required to fully understand the actual impacts and adjust mitigation efforts. Predictions of environmental impacts depend on the reliability of the data, models, and assumptions underlying them and performance evaluations are needed to validate predictions.

To assess *S. chinensis* use and movement through the project area, direct visual surveys could be supplement by applying passive underwater acoustic monitors, remote controlled surface video systems, and tagging of individuals with satellite transmitters. Passive acoustic monitoring (PAM) systems are increasingly being used for various management and mitigation applications, the latter most recently for emerging marine wind farm development. A recent review by Van Parijs et al. (2009) highlights the range of applications that have been implemented. Given the scale of the current project two types of PAM systems might be considered based on requirements. Both are well suited for site-specific analysis.

Initially during impact assessment and/or construction, a network of archival PAM units, such as Timing Porpoise Detectors ((T-PODS), could be deployed to help establish baseline dolphin usage of the project footprint. These recording acoustic monitoring sensors[4] that detect echolocation clicks in small cetaceans (Thomsen et al. 2005) and have become routinely used for impact assessment and monitoring programs for small cetaceans (Kyhn et al. 2008). They are often deployed on moored buoys and retrieved for analysis and maintenance and have been used effectively for assessing environmental impacts of marine wind farms (Teilmann et al, 2002, Carstensen et. al. 2006)) and US Naval activities (Hildebrand, 2005) on marine mammals. PAM systems provide

[4] T-PODs and C-PODs (PODs) are fully automated, static, passive acoustic monitoring systems that detect porpoises, dolphins and other toothed whales by recognizing the trains of echo-location clicks they make to detect their prey, orientate and interact.

continuous activity records rather than episodic observations and can be used to detect patterns of activity.

Post construction, an integrated real-time PAM system with deployed sensors linked by cable to an on-site recording station and connected by the Internet to research and academic institutions for archiving and analysis, may increase useful information on the size and movement of this population, its behavior-ecology, and the performance of implemented mitigation. The system would include a secure and weather protected facility equipped with recorders and controllers for remote video cameras, static passive acoustic monitoring systems (both real time and archival), and sound generation systems as well as an automated weather station.

The recommendation for PAM is intended to improve monitoring the coverage and cost-effectiveness compared to observer-based visual site-specific data collection and to allow monitoring during low visibility conditions. By taking advantage of the soniferous nature of the target organisms (i.e. dolphins and selected prey), PAM can be used to identify prey species and dolphin activity in the area as well as sound levels during construction and operation. Passive acoustic systems eliminate the problem of confounding presence of humans and boats. Used in advance of construction, it could help establish baseline conditions in terms of habitat use and abundance. During construction, it can provide an alert to the presence of cetaceans in the construction footprint even in when they may not be visible. When integrated with surface video or photographic data it could be used to monitor movements, habitat usage, group size, and identifiable behavior patterns thereby providing critical information for protecting this population. Cockeron et al. (1997) described a preliminary approach for using acoustic methods to estimate dolphin density and suggested this might complement visual surveys to provide information on habitat utilization. This type of passive acoustic monitoring and assessment approach has been stipulated as a condition of a construction permit for dredge and fill project in the vicinity of beluga whales (*Delphinapterus leucas*) in Alaska[5].

Due to the large volume of data collected using PAM systems, a combination of computation methods are required for effective interpretation. Acoustic data is generally transformed into visual data and pattern recognition methods are then used to facilitate auto-detection, and classification. This integrated automation allows practical monitoring and assessment at a level not previously possible. In the US, these methods are currently being used in conjunction with monitoring and mitigation programs to aid compliance with the Endangered Species Act and Marine Mammal Protection Act. An example is the Right Whale Listening Network, deployed off the coast of Massachusetts, is used to monitor the presence of endangered North Atlantic right whales (*Eubalaena glacialis)* and mitigate potential impacts by providing warnings to vessel captains transiting the area.

Real time monitoring equipment could be remotely controlled (telecommands) by computer interface, but would allow access for on-site monitoring and maintenance. Recording equipment connected to deployed video cameras, passive acoustic monitors,

[5] Port of Anchorage Alaska, Marine Terminal Redevelopment Permit, USACE July 2007.

underwater hydrophones and speakers (perhaps near FADs adjacent to the channel) would provide archival records. This approach would enable researchers integrate surface visual and underwater acoustic data. Since modern petrochemical plants routinely have internal video monitoring systems and staff skilled in maintenance and operation- adding weatherproof cameras on elevated poles/towers would be a relatively minor additional expense.

There are a range of innovations possible with a facility that has integrated real time sensors. For example, pattern recognition methods (for visual and sound data) might be used to alert monitors to the presence of dolphin in the area and this might be used to inform operators of vessels so they can make adjustments to avoid strikes or disturbance. Real time monitoring of dolphin presence and ship passage could also be used to schedule acoustic attraction actions or trigger avoidance measures. The system could also aid in evaluating conditioning experiments in using sound (underwater speakers) to encourage transit around the island and across the channel.

If the project is implemented, active acoustic monitoring (AAM), such as deployed dual frequency identification sonar (DIDSON[6]) units (high-frequency multibeam sonar), may be useful for near- field monitoring of enhanced habitats in key areas. The DIDSON is a relatively new technology that created near-video quality images using uses sound-distorting lenses. Within its limited range (30m), it creates images that provide enough resolution (outline, shape and fin detail) to help identify the fish or marine mammals in its field. It is used with integrated software that can enable fish to be counted and measured. It is well suited for direct observations in darkness or low visibility water. In this case, it could be used to monitor the performance of midwater attractors or constructed reefs and observe dolphin feeding behavior around these structures. DIDSON[7] has recently by approved for use with marine mammals by US NOAA and was recently used to show how sea lions feed on herring at depth[8].

### 3.3 Mitigation feasibility studies

The effectiveness of any innovative mitigation and monitoring methods proposed will need to be evaluated to assure compliance and performance. In some cases, approaches may involve technology that is non-standard (new reef and FAD designs), has not been tested with this target species, or requires system integration (such as acoustic and visual observations) to develop useful interpretation methods. To evaluate mitigation effectiveness, feasibility studies are recommended to evaluate performance in advance of full scale implementation.

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[6] The use of trade or firm names within this paper is for user information and does not imply endorsement by Aquabio, Inc. of any product or service.
[7] The standard DIDSON operates at two frequencies (1.8 MHz and 1.1 MHz) and provides images of objects from 1 meter to over 30 meters in range. DIDSON is small in size and requires only 30 watts at 24Vdc.
[8] Sonar Reveals How Herring Respond to Predators By R. Heintz, K. Boswell and J. Moran. NOAA Research Archive of Feature Article

Feasibility studies are particularly needed for potential near-site habitat enhancement methods, some sound disturbance mitigation methods, and underwater passive or active acoustic technologies. For habitat enhancement, studies are needed to test the stability, life expectancy and ecological performance. Shallow water depth, soft bottom sand/mud substrate, and oceanographic conditions during storms pose challenges for habitat enhancement. The application of remote acoustic/visual monitoring methods should be tested in advance and this data may help to establish baseline conditions before construction commences. Midwater devices and/or acoustic means to promote dolphin passage of the potential barrier posed by the island and channel will also require study prior to implementation. Based on the performance in initial testing, appropriate measures can be adapted and scaled for implementation.

## 4.0 Summary and Conclusion

To ensure the preservation of the ETS population, the facility should not be built at this site or anywhere else within the limited ETS population habitat. This position is based on the endangered status of the population, the uncertainty in predicted impacts, and the currently unproven efficacy of identified mitigation options. The highly vulnerable status of the small ETS *S. chinensis* population justifies a precautionary approach to ensure that this project does not become the tipping point for the extirpation of this endangered population.

Due to the small size of the ETS population and the location of the proposed facility, all five risk factors considered here may individually result in significant adverse impacts. Since the project impact on the population is the joint consequence of all these, and perhaps additional factors, the cumulative impact presents a credible risk of population extirpation. Some factors may be partly mitigated. For example, sound disturbance, vessel strikes, and the probability of a catastrophic spill can be reduced by applying appropriate mitigation measures. It may be possible to reduce the impact on prey species, but this is also quite uncertain, due to site conditions and untested technology. Habitat and/or population fragmentation, if it occurs, may be the most significant long-term impact and one for which there is no proven mitigation and for which preconstruction testing is not practical. Recent modeling and analysis by Huang and Chou 2010[9] suggests that even very small change in the scale of anthropogenic impacts will significantly change the risk of extinction for humpback dolphin at the current population size.

Although some mitigation is certainly possible, available mitigation is inadequate to assure the survival of the ETS population. However, development sometimes proceeds despite adverse environmental impacts and should this project proceed, it is critical that preventive and compensatory mitigation measures be implemented and monitoring be conducted to enable implementing additional mitigation as needed. The suggested

[9] Huang, Shiang-Lin**,** Lien-Siang Chou. 2010 Trend and vulnerability of eastern Taiwan Strait population of humpback dolphin, *Sousa chinensis*: Can this population survive? Workshop on population connectivity and conservation of Sousa chinensis off Chinese coast. June 4-7, 2010, Nanjing, China

adaptively managed mitigation differs from traditional mitigation approaches in that it allows selected monitoring and mitigation activities to proceed despite some uncertainty regarding how best to achieve desired outcomes. When time is of the essence or when projects have been approved without adequate evaluation, it provides flexibility to make changes based on conditions that may arise as construction gets underway or the performance of initial mitigation efforts. In this case, it might allow more than one approach to monitoring or mitigation to be tested in parallel and then use initial results to determine how best to invest research and mitigation funds to achieve the greatest return-on-investment. The selection of candidate mitigation measures is best made by an interdisciplinary team of specialists familiar with the species, local environment, and planned implementation methods.

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