Potential Impacts to *Sousa chinensis* from a Proposed Land Reclamation along the West Coast of Taiwan[1]

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Abstract: The creation of a man-made island is proposed for the development of a petrochemical refinery and industrial complex in Changhua County, Taiwan. The constructed island will extend across the normal depth range and movement corridor of the critically endangered Eastern Taiwan Straight (ETS) population of *Sousa chinensis*. The objective of this initial scoping analysis and review was to anticipate potential impacts for further study. Anticipated risk factors for *S. chinensis* include habitat fragmentation, reduction in prey resources, contamination, acoustic disturbance, and increased vessel strikes. The nearshore island creation together with the generation of substantial anthropogenic sound during the 3-4 year construction period may synergistically create an effective barrier that restricts *S. chinensis* movement and reduces fish prey availability. This barrier may fragment the population and lead to its extirpation. Prey availability will be reduced due to loss of about 4000 ha of productive subtidal habitat, masking vocalizations of soniferous prey, and disrupting normal echolocation for prey detection and/or social communication for cooperative feeding. Reduced food resources can affect the fitness of individuals and the dynamics of the population. Given the small size of this population, potential adverse impacts are likely to be significant, although currently difficult to accurately predict due to the complex interactions of variables and limited information on this recently described population, existing conditions at the site, and proposed construction and pollution control procedures. These preliminary findings suggest that construction at the proposed site will place the viability of the ETS population at risk.

Keywords: Indo-Pacific humpback dolphin, Chinese white dolphin, impact assessment, man-made islands, coastal development, *Sousa chinensis*

1.0 Introduction

Taiwan is a densely populated island with limited land suitable for large industrial development projects. Land reclamation via hydraulic filling is frequently used to create industrial and science parks along the central west coast. Although environmentally disruptive to the coastal ecosystem, the reclamation approach is apparently administratively, economically, and/or politically easier than alternate site development approaches. This development approach reflects a variation of Garrett Hardin's "tragedy of the commons."[3]

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

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[3] 1968. "The Tragedy of the Commons". *Science* 162, 1243-1248.

In this case, public (common) inter and subtidal land is reclaimed by industrial developers acting independently until the common coastal habitat can no longer provide the ecosystem services needed to support its former biological productivity and diversity. Although industrial production does increase, coastal natural resources that are held in trust for the people by the government, are diminished as resource limits apply.

The creation of a man-made island is proposed for the development of the Kuokuang Petrochemical Technology's industrial complex just north of the mouth of the Chuoshui River in Changhua County, Taiwan. Among the communities and species at risk in the zone of impact is the endangered Eastern Taiwan Strait (ETS) Indo-Pacific Humpback Dolphin (*Sousa chinensis*), which is dependent on central west coast shallow water habitats. There was limited evidence of *S. chinensis* in Taiwan waters until about 2002 and information on the status and trends of this small population is still limited. However, there is a consensus among marine mammal specialists (Wang et al 2004a; 2007a), conservationists, and NGOs that this is a highly vulnerable population in urgent need of conservation and restoration.

The objective of this scoping analysis and review is to highlight anticipated impacts to the ETS population of *S. chinensis* from the proposed land reclamation and industrial development and identify data gaps that need further research before a decision to build at this site is made. Scoping is an early important step in impact assessment that identifies important issues to be considered, information needed for decision making, and significant effects to be considered further in the Environmental Assessment process. This review is presented from the perspective of a risk analyst and is based on what is known or can be inferred about behavior-ecology of *S. chinensis* from earlier work on this and other cetacean species, impacts arising from similar coastal construction projects, and information on the coastal habitats.

2.0 Current Situation

2.1 Status of Eastern Taiwan Strait *S. chinensis* population

The ETS population of *S. chinensis* occupies a linear home range of about 500 km^2 along the central west coast of Taiwan (Figure 2-1). Available information suggests this population consists of less than 100 individuals (Wang et al. 2004a; 2004b; 2007a; Chou et al. 2009[4]). The ETS population is critically endangered[5], is a Level One[6] protected species under Taiwan’s Wildlife Conservation Act, and resides in a habitat with extensive anthropogenic impacts. Without further protection, it may be vulnerable to extirpation. With respect to the proposed construction, vulnerability consists of two main elements; exposure and sensitivity. Exposure is a measure of the level of project impacts this population is likely to experience at this site. Sensitivity is a measure of whether and how this population is likely to be affected

[4] Chou, L.S., 2009. Population status of *Sousa chinensis* in the coastal waters of western Taiwan. Presentation at symposium on The Restoration of Food Habitat for *Sousa chinensis.* National Taiwan University, Taipei, Taiwan 20 Nov. 2009.

[5] It is listed by the IUCN (2008) as Critically Endangered.

[6] Level One provides this species with the highest level protection under this act.

by anticipated project impacts. There currently appears to be insufficient information to adequately address either of these elements.

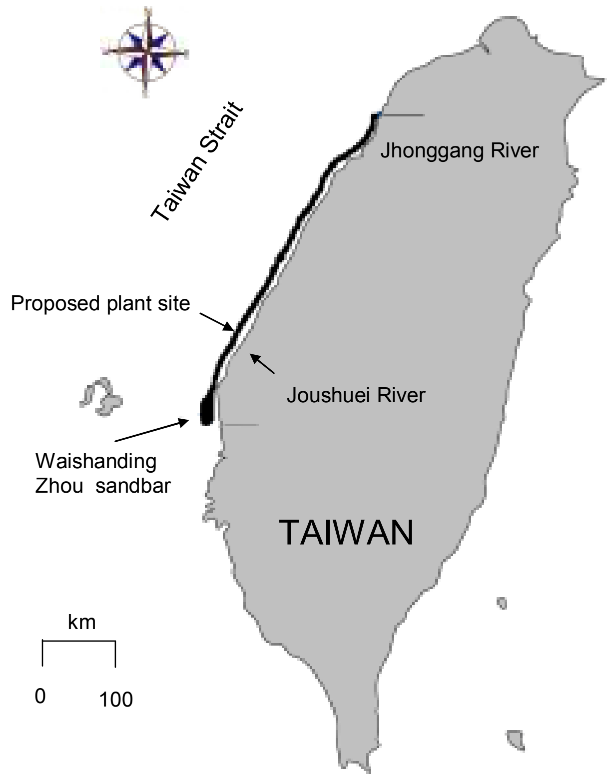

Figure 2-1. Habitat range (black region) of the Eastern Taiwan Strait population of *Sousa chinensis* is generally restricted to a narrow corridor less than 20m deep and within 4 km from shore.

The small ETS population, with its inherent reduced genetic and demographic variability, is particularly vulnerable to even minor changes or losses that might be less of a concern with a larger population (Wang et al. 2007b). The death or injury to even a small number of females or young may have significant consequences on population viability. Small cetacean populations are particularly vulnerable to anthropogenic disturbances due to their low birth rates, late sexual maturity, and prolonged dependence of the young on adults. A number of existing threats to this species including habitat loss, reduced freshwater flow to estuaries, fishing gear entrapment, pollution discharges, vessel strikes, and underwater noise. There was general agreement among a team of marine mammal specialists that existing impacts should be mitigated using best available methods to prevent the extirpation of this species from Taiwan waters (Wang et al. 2007a).

2.2 Cumulative environmental impacts within existing ETS population range

Over the last 30 years, the coastal corridor habitat of the ETS population has been subject to multiple impacts including extensive land reclamation for industrial development (Figure 2-2) and pollution. These impacts have significantly degraded habitat used by *S. chinensis* for feeding, reproductive and nursery areas as well as intertidal and mangrove areas that support its prey fish species. To fully evaluate the impacts of the currently proposed development, it is essential to consider them in the context of cumulative impacts on this population. Cumulative impact is the impact on the environment that results from the incremental impact of the proposed development when added to other past, present, and potential future impacts regardless of the source of such actions (Figure 2-3). Potential future impacts include the fifth stage expansion of Formosa Plastics Group's Mailiao industrial park, the Guokuang Petrochemical Park, the Erlin Central Science Park, and potential marine wind farms (Lin et al. 2009).

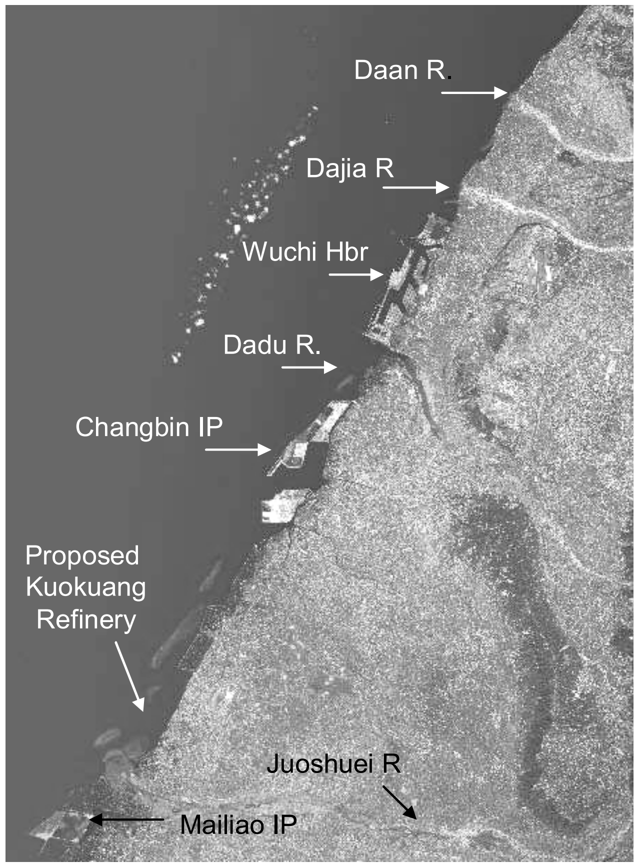

Figure 2-2. Past coastal land reclamation within ETS *Sousa chinensis* habitat reflecting extensive cumulative impacts from industrial parks (IP) and harbor complexes. (NASA)

Although the minimum viable population size is not known, the current small population size, restricted movement patterns, and cumulative habitat impacts may have brought the ETS population to a critical threshold point. Any significant impacts arising from further development may cause it to decline abruptly leading to extirpation. The current approach to impact assessment, which considers each development independently without reference to cumulative regional impacts, often leads to a 'tyranny of small decisions' (Odum 1982)[7] and the loss of important biodiversity. In this case, a series of independent decisions about the development of the central west coast of Taiwan, made in the absence of effective regional

[7] Odum was expanding on concept introduced in an essay by Alfred E. Kahn (1966) "The tyranny of small decisions: market failures, imperfections, and the limits of economics" *Kvklos*, **19**:23-47.

land use planning, has resulted in a degraded ecoregion already unable to provide the level and scope of ecosystem services it produced in the past.

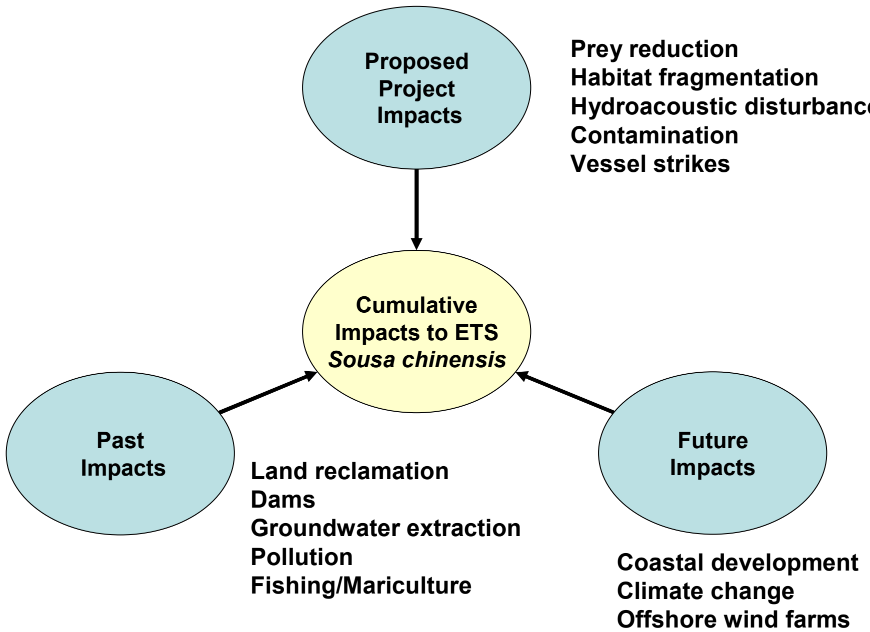

Figure 2-3. Cumulative Impacts to Eastern Taiwan Strait Population of *S. chinensis*

3.0 Anticipating Potential Impacts

Environmental impact assessment is an anticipatory management tool designed to provide decision makers with an idea of the likely consequences of the proposed action. At present, there is limited data on the ETS population and environmental conditions at this site. These limitations constrain the development of a realistic impact assessment and are sufficient reason to postpone any construction until these data gaps and uncertainties are addressed. A forward-looking and flexible anticipatory/adaptive approach (Figure 3-1) may help use existing information to effectively develop research monitoring priorities that can inform a more comprehensive impact assessment.

Decisions to protect or restore natural resources are often made as a reaction to impacts that emerged over time, but were not foreseen or addressed until they became critical to an important resource. Failing to respond to such emerging problems can jeopardize species survival and regional biodiversity. Environmental impact assessment can be used to predict potential project impacts to the ETS population, evaluate priority risks, and suggest further surveys and studies needed to reduce key uncertainties, test critical assumptions, and plan contingent mitigation.

Taking anticipatory action to prevent environmental degradation is fundamental to the precautionary principle. This applies when there is either an absence of complete proof of harm or uncertainty about causal links[8] (Dethlefsen et al 1993). Since the proposed facility may be built as planned despite fundamental uncertainties or limited field data and construction expedited for economic reasons, it may be necessary to develop an adaptive mitigation plan based on a review of past projects impacting *S. chinensis* or other cetacean species elsewhere Sheehy 2009).

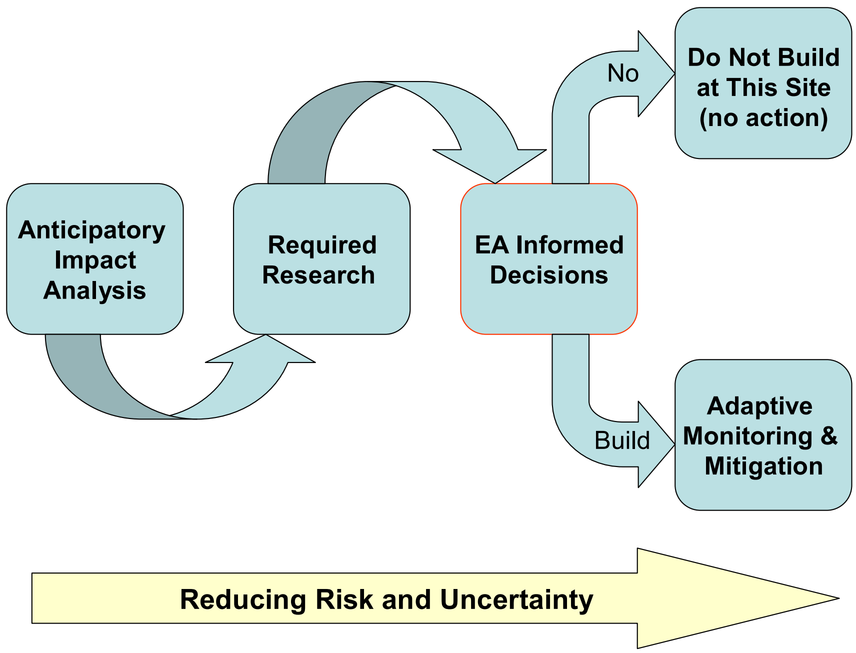

Figure 3-1. An anticipatory/adaptive approach can focus essential research to inform key decisions and reduce uncertainties with respect to impacts and mitigation performance.

4.0 Potential Project Impacts and Risk Factors for *Sousa chinensis*

The proposed land reclamation for the Kuokuang refinery and petrochemical complex will produce air, surface and ground water, and coastal morphology impacts. This paper focuses on potential impacts to the ETS population of *S. chinensis* that should be anticipated and fully addressed in the impact assessment. Figure 4-1 is a cause and effect diagram illustrating five impacts of concern for the ETS population; prey loss, barrier creation, acoustic disturbance, potential contamination, and vessel strikes. If the project is implemented, knowledge of likely impacts can be used to develop mitigation plans. Figure 4-2 illustrates a general impact assessment framework that was adapted from one developed for port development[9].

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[8] "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." the Rio Conference, or "Earth Summit" in 1992. Principle #15

[9] NEW! Delta is a European project involving ten partners from France, the United Kingdom, Belgium and the Netherlands. http://www.newdelta.org.

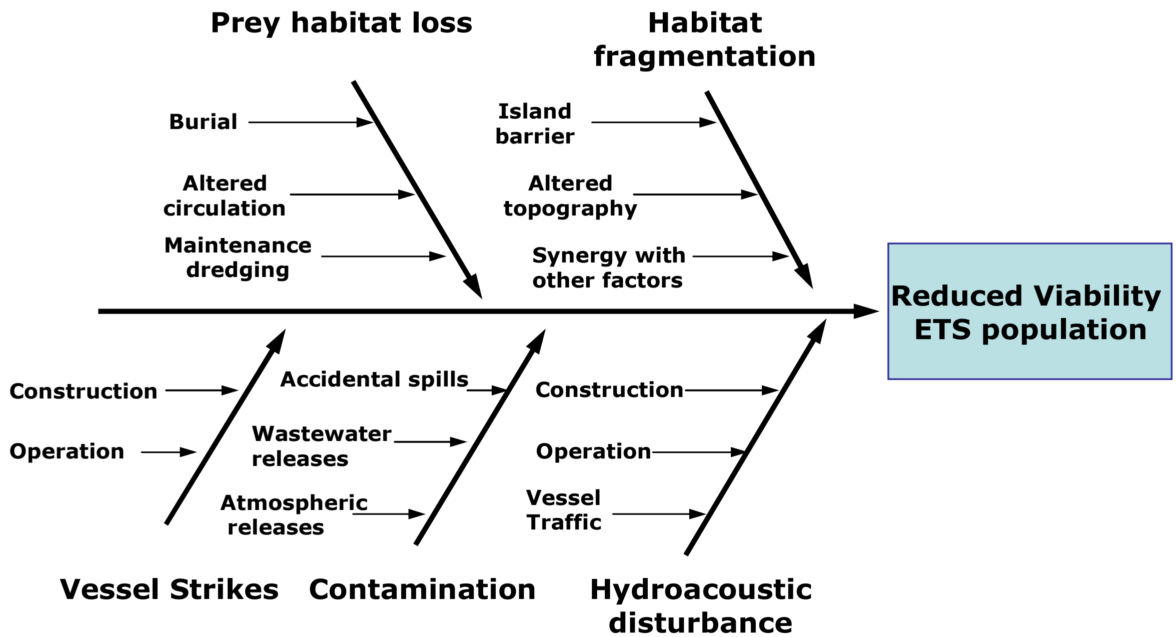

Figure 4-1. Cause and effect diagram for five potential adverse impacts to the ETS population of *S. chinensis* from the proposed Changhua County land reclamation project.

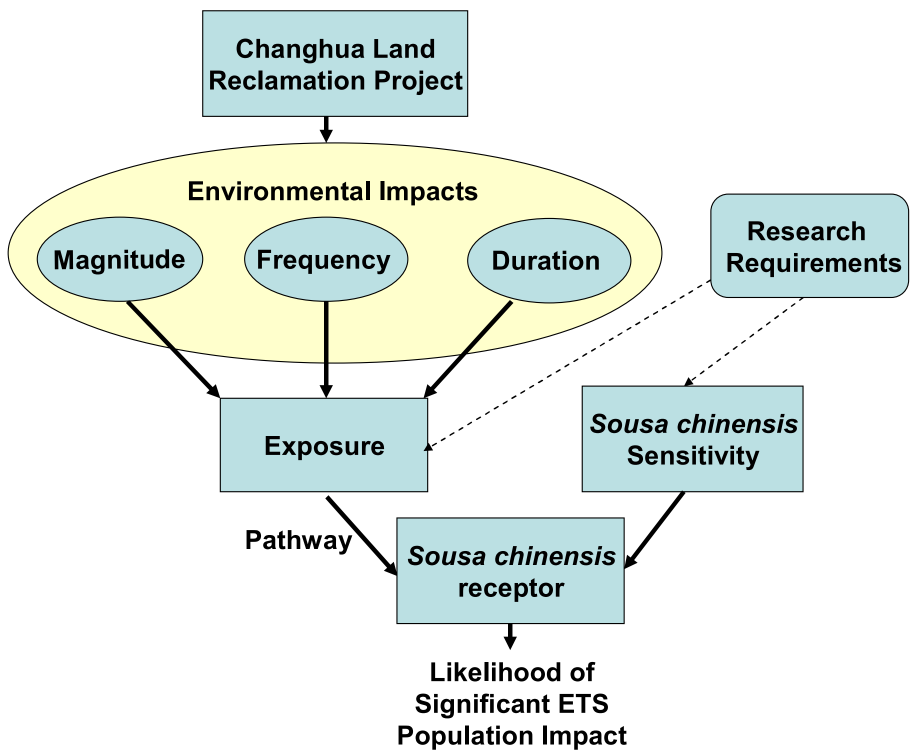

Figure 4-2. Impact assessment approach indicating the need for additional research related to the exposure and sensitivity of *S. chinensis* to anticipated project environmental impacts.

Not all impacts are lethal; however, the cumulative acute, chronic, and sub-lethal impacts may eventually result in a significant reduction in the at-risk population. Some factors, such as the physical barrier, sound generated by construction, and vessel strikes may act synergistically. Population-level impact assessment will need to link these and other impacts to future changes in abundance or demographic parameters, such as survival or birth rate.

4.1 Subtidal habitat loss and reduction in prey fish availability

The proposed construction will directly impact about 4000 ha of productive soft bottom feeding habitat by directly burying subtidal habitat in the area occupied by the ETS population or its prey. Burial (less than 3000 ha) will permanently remove the associated infaunal and epibenthic communities, displace planktonic species, and reduce the ecosystem services they provide. In addition to direct burial, disturbance and degradation due to construction and maintenance dredging, large vessel traffic, as well as altered circulation patterns will further impact benthic production. These losses may adversely impact the food web supporting the ETS population. Since the quantity and quality of food an animal can efficiently obtain affects its survival, growth, and reproductive success, food resource reductions can affect the fitness of individuals and the dynamics of the population.

4.1.1 Identifying probable prey fish target species

There is limited data on the prey consumed by the ETS population or the production base that supports these species. Probable prey species were identified by examining data on prey known to be commonly consumed by other populations of *S. chinensis* and then comparing them with taxonomically similar prey species abundant within the ETS population habitat. Prey items from China, South Africa, Australia and India were compiled and then compared to fish survey data (Chen 2009[10], Shao et al. 1993; Hung and Chiu 1991) from western Taiwan.

A review of the literature indicated *S. chinensis* is an opportunistic generalist piscivore that uses passive listening and echolocation to search for prey and hunts in small groups. Throughout its global range, foraging behavior seems to involve consistent utilization of both demersal soniferous shoaling prey and schooling pelagic prey. *S. chinensis* appears to adapt to available local prey resources and pursues them in a range of habitats including reefs, lagoons, estuaries and mangrove areas in addition to the type of sand-mud bottoms found along the west coast of Taiwan. The one consistent factor across *S. chinensis's* range is that it is generally not found in waters greater than 20 m or more than 4 km from shore and is thus restricted to nearshore and estuarine food resources.

Table 4.1 lists fishes identified as common diet items of *S. chinensis* from other regions along with characteristics of these species relevant for impact assessment and mitigation

[10] Chen, M.H., 2009. Fish assemblages along the coastal waters off western Taiwan in relationship to the distribution of *Sousa chinensis*. Presentation at the Symposium on the restoration of food habitat for Sousa chinensis, National Taiwan University, Taipei, Taiwan 20 November 2009.

Table 4-1

Characteristics[11] of Primary Prey Species of *Sousa chinensis* in China[12], Australia[13], South Africa[14] and India[15]

Species	Environment	School /shoal	Estuary use or dependency	Soniferous	Primary diet items	Use
Trichiurus lepturus [16]	BP; A	school	muddy shallow coastal bottom, enter estuaries		fish, squid and crustaceans	HC; GF
Trichiurus sp[14]	BP; A	school	brackish/marine; estuaries/ lagoons/brackish seas, mangroves		fish, squid, crustaceans euphausiids	HC; GF
Thryssa spp[14]	P-N	school	use estuaries, perhaps nursery area (estuaries Taiwan)		plankton and fry, benthic invertebrates	MC; BA
Thryssa vitrirostris[16]	P-N	school	entering estuaries and lagoons (perhaps nurseries)		plankton, estuarine fish fry	MC; BA
Mugil cephalus[16]	P	school	estuary use (estuarine Taiwan)	yes	microalgae, plant detritus, sed.	CO, CU
Liza richardsonii[16]	D	school	estuary use, surf zone (Liza estuarine Taiwan)	yes	diatoms mysids	CO
Coilia sp.[14]	P	school	use estuaries		plankton, invertebrates	variable
Somber japonicus[16]	P-N; O adults near bottom in day	school by size	no	no	copepods, other crustaceans, fish, squid	HC; CU
Sardinella longiceps[17]	P-N: O	schools	no		phytoplankton, diatoms, small crustaceans	HC

[11] Primary ref. FishBase, 2009. Froese, R. and D. Pauly. Editors. World Wide Web electronic publication. www.fishbase.org, version (11/2009).
[12] Species listed in N.B. Barros et al., 2004. Hung et al. 2004
[13] Species listed in G. Parra and M Jedensjo, 2009
[14] Species listed in G.J.B. Ross, 1984; N.B Barros and V.G. Cockcroft, 1991
[15] Species from A.A. Krishnan et al., 2007

Pomadasys sp.[15]	D	shoal	many use estuaries some reefs	yes -SPT	zoobenthos	CO, AT aquarium
Pomadasys trifasciatus[15]	BP	shoal	inshore waters, shelf estuaries/lagoons/brackish seas	yes SPT	crustaceans	
Pomadasys commersoni [16]	D-O: RA	shoal	estuaries juvenile nursery area (dependent)	yes SPT	benthic invertebrates	CO: GF; CU
Pomadasys olivaceus[16]	D: RA	shoal	tidal estuary mouth and shallow marine	yes SPT	shrimp, mysids; small invertebrates	CO,: BA, CU
Johnius sp.[14]	D	shoal	use estuaries, lagoons, brackish seas		benthic invertebrates	MC; CU
Collichthys lucidus[14]	D-O	Some-times schools	use estuaries, lagoons, brackish seas	yes. SBR	benthic invertebrates	MC; AT
Larimichthys crocea[14]	BP; O		brackish /marine	yes, SBR	benthic invertebrates	HC; CU
Otolithes ruber[16]	BP; A		soft and hard bottoms including reefs	yes SBR	fishes, prawns, other invertebrates	CP; GF
Diplodus sargus [16]	D-O	schools	Coastal rocky reef areas, *Posidonia oceanica* beds, estuary nursery	yes	shellfish and other benthic invertebrates	MC; CU
Rhabdosargus sp. [16]	BP; O	shoal, young school	estuary dependent juveniles, surf zone spawn near estuary	?	macrophytes, benthic invertebrates, mollusks, amphipods	MC; GF; CU
Pachymetopon sp. [15]	D-N	shoals	no, marine, rocky substrate	?	benthic invertebrates	CO; GF
Apogon sp.[15]	D	shoal	no, marine?	yes	fish	MC; AT
Sillago spp.[15]	D	school	coastal shallow protected waters, (estuaries Taiwan)		polychaetes and benthos	CO; CU

Table 4-2 **Characteristics[16] of Some Probable Prey Species [17] of the *Sousa chinensis* ETS Population**								
Species	**Environment**	**School /shoal**	**Estuary use or dependency**	**Depth Range (m)**	**Soniferous**	**Primary diet items**	**Trophic Level SE**	**Use**
Ilisha melastoma	P-N; A	school	coastal waters, enters estuaries	5-20	swimming sound	zooplankton, small benthic crustaceans & mollusks	3.45 s.e. 0.47	MC
Ilisha elongata	P-N	school	inshore, enters estuaries, lagoons	5-20	swimming sound	benthic crustaceans. zooplankton, fish	3.79 s.e.0.61	HC
Thryssa spp.	P-N	school	most inshore: some enters estuaries	<50		benthic invertebrates; planktonic crustaceans,	2.82-3.45	MC; BA
Thryssa kammalensis	P-N; O	school	brackish; inshore marine	1-20		planktonic crustaceans, detritus, benthic invertebrates	3.08 s.e.0.36	SF
Encrasicholina heteroloba	P; RA; O	school	inshore, estuaries, deep bays	20-50		planktonic crustaceans, zooplankton, fish	3.27 s.e. 0.37	MC; BA
Nematalosa come	P-N	school	estuaries, lagoons, brackish seas,	10-13	yes (air bubble though anal pore)	phytoplankton; planktonic and benthic invertebrates, detritus	2.76 s.e.0.28	MC, SF
Spratelloides gracilis	P-N	inshore school	marine, coastal, lagoon, seaward reefs	10-50	yes, pre-spawning?	planktonic invertebrates	3.04 s.e 0.16	MC; BA
Pennahia macrocephalus	D	shoals,	marine, coastal, bays, coral reefs	3-100	yes (SBR)	benthic invertebrates and fishes	4.08 s.e.0.64	HC

[16] Primary references: FishBase, 2009. Froese, R. and D. Pauly. Editors. World Wide Web electronic publication. www.fishbase.org, version (11/2009). and Shao. K.T. The Fish Database of Taiwan. WWW Web electronic publication. version 2009/1 http://fishdb.sinica.edu.tw, (2010-2-19)
[17] Initial species list adapted from M.H. Chen 2009

Pennahia pawak	BP	shoals	marine, coastal, bays	3-50	yes (SBR)	benthic and pelagic crustaceans	3.3 s.e.0.41	CO
Chrysochir aureus	BP	shoals,	shallow coastal, bays, brackish	1-20	yes (SBR)	benthic crustaceans	3.5 s.e.0.50	MC
Johnius amblycephalus	D	shoals	shallow coastal waters, estuaries, & coral reefs	3-40	yes (SBR)	benthic invertebrates	3.3 s.e 0.40	MC
Arius maculatus	D	occasional schools	inshore waters, lagoons, and estuaries	10-100	yes, spines-squeaking	benthic invertebrates and small fish	3.36 s.e 0.46	CO
Valamugil cunnesius	D; C	aggregate during sea spawning	estuaries and backwaters, young frequently enter freshwater	0-40	yes	detritus, plants, phyto- and zooplankton, organic matter in sand and mud	2.41 s.e 0.21	CO; BA
Trichiurus lepturus	BP; A	juveniles and small adults school	muddy bottom, often enter estuaries	0-400		juveniles- euphausiids, crustaceans, fish. adults- fish; squids & crustaceans	4.45 s.e.0.77	HC; GF

Environment: P- Pelagic; D- Demersal; BP- Benthopelagic; N- Neritic; RA- Reef Associated; A- Amphidromous; O- Oceanodromous; C- Catadromous

Soniferous: SBR- Swim Bladder Resonation. SPT - Stridulation Pharyngeal Teeth; Swimming sound is also called hydrodynamic noise from densely schooling fish, but it's unclear whether or not this is audible to dolphins

Utilization: HC-Highly Commercial; CO-commercial; MC-Minor Commercial; GF-Game Fish; CU- Cultured; SF- Subsistence planning: habitat type, estuarine relationship, soniferous behavior, typical prey, and commercial or recreational use. It confirms that prey fishes are generally similar taxonomically across the several populations and include the families Clupeidae, Engraulidea, Mugilidae, Scianidae, Haemulidae, Sillaginidae, Trichiuridae, Apogonidae, and Sparidae. As observed for some other dolphin species, more than half the prey fish are soniferous, providing a means for *S. chinensis* to locate prey in murky water conditions where visual perception is limited. Many of the species exhibit shoaling or schooling behavior that provides a broader or denser target for active echolocation. Schooling behavior is particularly common in pelagic prey. More than two thirds of the species also have some level association with estuarine habitats.

Table 4-2 lists some of the probable prey fishes identified by Chen (2009)[10] with the same details included in Table 4.1 along with the depth range and estimated trophic level. The basis of the original species list was taxonomic similarities to prey in Hong Kong/China and current relative abundance based on recent fisheries surveys within the geographic range of the ETS population in waters less than 20m (Chen 2009)[10]. The original list included four species of Pleuronectiformes, however they were omitted here since they seem unlikely (to this author) to be common prey despite their availability in the region. Their benthic habitat, lack of a swim bladder[18], lower energy value, and the fact that they neither routinely shoal nor school and are not known to produce sound suggests that they might be hard to detect either by passive listening or active echolocation. Although data is sparse and *S. chinensis* is highly opportunistic, there appears to be no evidence that similar species are preyed on elsewhere except possibly as an artifact of the habit of *S. chinensis* to feed by following trawlers. In addition to this list, other prey species, particularly other croakers, will also likely be included in the dolphin diet in Taiwan.

4.1.2 Prey Fish Impacts

The hydraulic sand fill method is the most widely adopted land reclamation method in western Taiwan. Sand material excavated by dredge from the subtidal areas along the coast is used as fill to create dry land for development. It has been suggested that the source of the fill material will come from the channel and industrial harbor dredging, but this may not be sufficient to meet fill requirements. Two similar projects along the west coast (Kao et al. 1998) were reviewed for comparison purposes. The Changhua Industrial Park constructed during 1996-2000, reclaimed 3778 ha and required 147×10^6 m^3 of fill. The construction at Mailiao in Yunlin County (1994-1997) reclaimed 2250 ha of land and required 74×10^6 m^3 fill. Assuming that the topography is somewhat similar, the fill requirements for the Kuokuang refinery are 4estimated at 30-40,000 m^3/ha. The proposed Kuokuang refinery land reclamation is projected to be about 4000 ha (including the harbor at less than 1000 ha, which will be a source of fill), suggesting that on the order of 105×10^6 m^3 of additional fill will be required for construction.

[18] All fish reflect sound, but those with a gas-filled swimbladder will scatter more sound than an identically sized fish without a swimbladder.

Many past actions have contributed to the loss and degradation of essential prey species habitat along the west coast. These include estuarine, lagoon, and coastal habitat loss; pollution from industrial, agricultural, and urban sources; reduced river flows due to water utilization, mariculture; and overfishing. Soft bottom habitats, especially near rivers, sequester nutrients that are re-suspended by wave action supporting plankton and benthic diatoms. These nutrients contribute to the production of benthic invertebrates that support many prey fish food webs. Reduced riverine flows due to water use by industry, agriculture, and municipalities starve the coastal sediment supply that is the only real requirement for soft bottom habitat.

Overall prey fish impacts are difficult to estimate due to lack of baseline data on what will be directly lost and uncertainties with respect to changes in the geomorphology and maintenance dredging requirements. To assess habitat and benthic production loss and degradation and determine the scale for any potential mitigation, the current production of the reclaimed area, the fill material sources, and the anticipated frequency of maintenance dredging must be determined. Except for those areas completely buried and frequently dredged, post construction benthic recovery in surrounding areas is expected. Sediment disturbance frequently initially stimulates settlement and abundance of opportunistic species such as polychaetes; perhaps temporarily increasing benthic secondary production. In addition, alternate hard bottom habitat will be created along the armored edge of the island. If these habitats remain uncontaminated, they may provide additional food for prey species. Unburied habitat recovery and alternate habitat creation must also be evaluated to determine net loss.

4.2 Blockage of normal coastal movement

Cockeron et al. (1997) and others have suggested that inshore marine mammals may be prone to habitat fragmentation (and perhaps genetic isolation) due to human disturbance. The ETS population inhabits a relatively narrow corridor nearshore waters extending approximately from just north of the Jhonggang River to the Waishanding Zhou sandbar on the south. Waishanding Zhou is a natural physical barrier extending offshore south of Joushuei river mouth (Wang et al. 2004a, 2007a Chou, et al. 2009[4]; Chou, 2009[19]). Chou et al. (2009)[4] observed that 95 % of sitings were in less that 15 m and within 3.0 km of shore. The proposed reclamation will extend about 4.5 km from shore to seaward wall of the harbor. Jefferson (1998) studied the Hong Kong population and noted that distance from shore is less relevant than the two primary aspects of the species' habitat preference: water depth and estuarine influence. If additional water is drawn from the Joushuei River to support plant processing, this will reduce its estuarine influence.

Since the proposed facility will create an artificial barrier extending across the normal depth range of *S. chinensis*, it may fragment this habitat and possibly the small population. A channel dredged to 27m will extend seaward from the island, and although *S. chinensis*

[19] Chou, L. S., H.Y. Yu, T.H. Lin, C.C. Lin, W. Chang, and C.H. Yen. 2009. Study progress and status of *Sousa chinensis* in Taiwan. Presentation at International Symposium on Cetacean Conservation, Xiamen, China 8-9 Nov. 2009.

apparently will cross deep channels in some areas (Jefferson 1998), this may contribute to the barrier. A buffer channel will separate the reclaimed island from the mainland to maintain water quality and reduce flood impacts, but its width and depth make it highly unlikely to serve as a means of dolphin passage and it will require frequent maintenance dredging. Figure 4-3 is a general plan for the proposed island annotated to show the normal depth range for dolphins that move along this stretch of coastline. The creation of this island will change surrounding bathymetry by altering erosion and deposition as was documented for the Yulin Offshore Industrial Estate site (Liu et al. 2002). Simulation modeling can help predict the general nature of these changes but, given the narrow depth range of *S. chinensis*, changes will alter normal movement pathways.

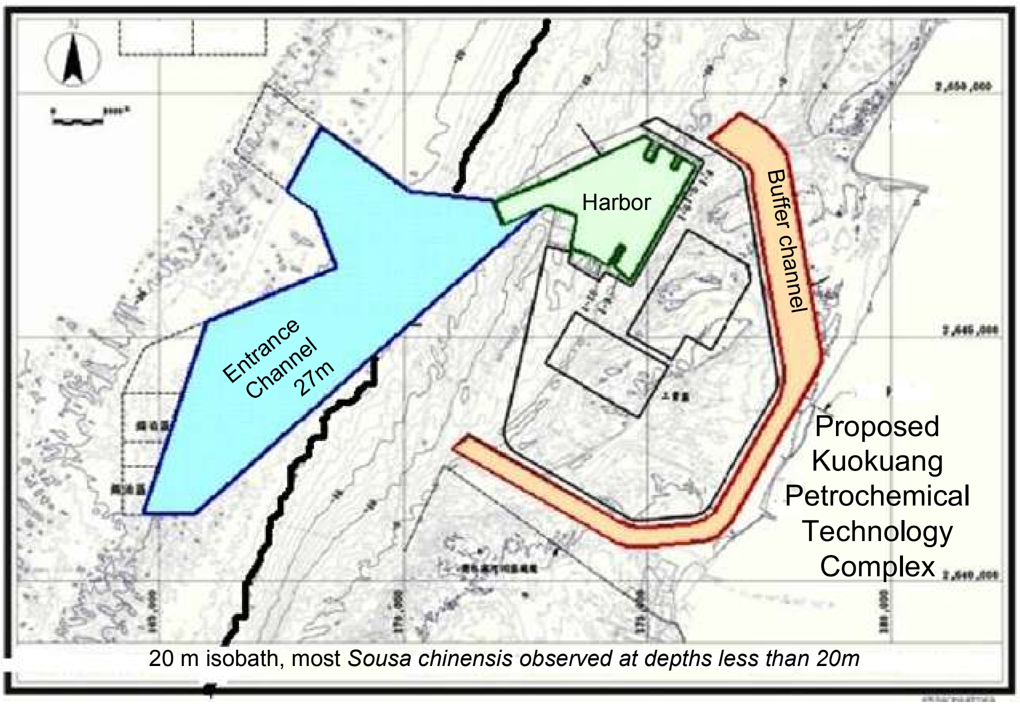

Figure 4-3. The proposed petrochemical facility layout illustrating that the facility will extend across the normal depth range of *Sousa chinensis* (to the 20m isobath).

Preliminary population trajectory and extirpation risk, assessed using age-structured Leslie Matrix population model suggests that if the habitat is fragmented and the barrier effectively isolates population elements on either side, it may lead to extirpation in Taiwan waters (Huang and Chou, 2009[20]). Due to the limited data on this population, this prediction is uncertain; however it strongly suggests a significant population impact if fragmentation occurs. This alone justifies a precautionary approach until these uncertainties are resolved. The recent functional extinction of the Chinese River Dolphin or baiji (*Lipotes vexillifer*) demonstrates that failure to preserve a critical population size for cetaceans can have serious consequences. Ten years before it was declared functionally extinct, about 100 baiji remained in the Yangtze River.

[20] Presentation at Symposium on the "Restoration of Food Habitat for *Sousa chinensis*" National Taiwan University, 20 Nov. 2009, Shiang-Lin Huang and Lien-Siang Chou

4.3 Hydroacoustic disturbance

Marine mammal reactions to anthropogenic sound can result in decreased foraging efficiency, higher energetic demands, reduced group cohesion, higher predation, and decreased reproduction. Construction generated underwater sounds, to which *S. chinensis* is sensitive, will impact the dolphins for varying distances from the site. Characterizing anticipated sound sources to assess those that *S. chinensis* is sensitive to and determining likely exposure of the ETS population should frame initial efforts to assess risk. Due to the scale of the construction, the duration of sound disturbance (3-4 yrs) may produce significant impacts.

4.3.1 Potential sound impacts

For all cetaceans, sound is vital for providing information about their environment, communicating with conspecifics, and finding prey (McIwen 2006). In addition to direct injury, there are three other concerns for cetaceans exposed to elevated anthropogenic sound levels; acoustic masking, behavioral disturbance, and threshold shifts. Masking results when anthropogenic sound covers a desired signal, such as mother-calf calling or prey sounds. Behavioral changes may include avoidance of an area or a change in activity in response to sound. Threshold shifts reflect impairment in the animal's ability to hear as a response to sound, such as that of an oncoming vessel, and this can reduce risk avoidance and feeding opportunities. Individual responses vary and have varying impact durations, but when sound persists long enough or disturbs important functions, population level effects are likely (Nowacek et al. 2007).

Some project underwater sounds may prevent *S. chinensis* from entering areas near construction sites (Tyack 2009) excluding them from their normal habitat. Efforts to protect porpoises from gill nets have clearly demonstrated that sound producing alarms can effectively exclude them from ensonified areas (Culik et al. 2001). Since the facility already extends across the normal depth range of this species, underwater sound avoidance or disturbance may exacerbate the island's barrier effect leading to population fragmentation. Sound impacts will depend on the source amplitude, frequency, and duration of the sources of sound and the hearing frequency and sensitivity of *S. chinensis* and target prey fish species.

Sound may impact dolphin feeding directly or interfere with prey species behavior, thereby expanding the feeding impact zone beyond the area buried by the island. For dolphins, project sounds can mask prey sounds, interfere with active prey searching, and disrupt coordinated group feeding efforts. Dolphins use both passive listening and active echolocation to locate prey species. More than half of the prey species identified for *S. chinensis* are soniferous and additional anthropogenic sound may mask prey fish vocalizations. Anthropogenic sound production may also impair the use of echolocation to find schooling pelagic prey. Bottlenose dolphins increase calling during feeding events (Acevedo-Gutiérrez 2004) and this communication can be masked by anthropogenic sounds, which may reduce group feeding efficiency.

Construction sound generation may also adversely impact soniferous prey fish species that also use sound to communicate. Sound is used by croakers, drums, and grunts to attract mates or to maintain group cohesion (Gannon et al. 2005). For centuries, Chinese fishermen have located spawning areas for drums by listening drumming sounds through the hulls of their boats. More recently, fishermen of Yulin County used passive listening methods to locate and then capture croaker. Sound production of the Black spotted Croaker (*Protoxide diacanthus)* was recently recorded near the Chuoshui River and the sound production suggested this area as a spawning site (Mok et al. 2009). Most fish sounds are low in frequency, generally 200 and 2000 Hz (Gannon et al. 2005). For example, the minimum and maximum fundamental frequencies for the *P. diacanthus* were 116 and 307 Hz respectively (Mok et al. 2009). This frequency range is also the within the sound generation range for many construction activities and masking may disrupt reproduction success for some Sciaenids.

Intra-species communication may also be masked by construction sounds (Nakahara 1999) and this may alter behavior. Persistent construction sound may alter normal social behavior by masking normal communication or increasing stress levels. It is not clear what the consequences of altering communications within and between *S. chinensis* groups may be, but certain exchanges, such as those between mother and calf, may be critical to calf survival, especially in turbid water with limited visibility. Although there is some evidence with *Tursiops aduncus* that suggests other dolphin species can adapt communication signals to avoid masking (Morisaka et al. 2005), however, given the level and spectrum of noise during construction this is unlikely to be possible.

4.3.2 Anthropogenic sound sources

Construction sound sources include dredging, pile driving, increased vessel traffic, breakwater/seawall construction, and, perhaps, soil improvement (consolidation). These sources can generate sound levels that are significantly above ambient levels and may propagate for 10-12 km or farther. Normal operations will also generate some level of underwater sound associated with maintenance dredging and vessel traffic in and out of the harbor.

Hydraulic dredging produces continuous underwater sound (20-1000 Hz) that has been shown to effect cetaceans in nearshore areas. Trailer suction hopper dredges (TSHDs) are planned for deep water dredging work[21]. While dredging, a 28,999 hp TSHD can generate broadband source sound around 188.3 dB re 1 μPa/ at 1m (LGL and JASCO Research 2005) and levels of 120 dB received levels at the surface could extend 3-4 km from the source. The recovered sand will be transported to the harbor area where it will be handled by a cutter suction dredge and piped to reclamation area. This second phase may include the use of anchored floating pipe and interim pumping stations to convey the material from the harbor pit to the reclamation sites. Since a considerable amount of the borrowed sand will come from the planned harbor and its entrance channel, the

[21] Personal communication Horace Nian-Tzu Wu, Hydraulic and Ocean Engineering Dept. Sinotech Engineering Consultants Ltd.

submerged portion of the dredge pipe will also provide a continuous source of sound, at least during part of the construction process. The observed effects of dredging on cetacean behavior have been quite variable and, further investigation is required. Dredging sound from propeller cavitations, draghead vacuuming, and submerged slurry lines can also mask transiting vessel sounds and thereby increase the chance of vessel strikes.

Piling creates high level of low frequency impulse sound that does impact marine mammals and fish. Extensive pile driving is anticipated since the previous construction in Yunlin County for the Formosa Plastic facility drove about 4.5 million meters of piles. Driving piles in-the-wet can generate shock waves that can disturb or kill fish. The construction of the harbor quays, chemical plant construction, and other facilities will likely involve extensive percussive pile driving. At 9 kHz, pile driving sound is capable of masking strong dolphin vocalizations within 10–15 kilometers and weak vocalizations up to 40 kilometers (McIwen 2006). During studies of construction involving percussive pile driving in Hong Kong, Würsig et al. (2000) and Jefferson (1998) observed that *S. chinensis* abundance in the area near construction decreased and their travel speed increased. Observations of porpoise behavior during pile driving in marine wind farms indicated that click clusters monitored on passive data loggers were reduced for extended periods after pile driving (Madsen et al., 2006).

Vessel sound sources are primarily propeller sounds, although at very low speeds hull radiated sounds may dominate. *S. chinensis* sound production (whistles 1.2-16 kHz and broadband clicks 2-22 kHz) overlap with the frequencies generated by boat traffic, suggesting that this sound noise may impair normal behavior (Schultz and Corkeron 1994; Van Parijs and Corkeron 2001). Measured responses of cetaceans seem to vary among species and with the amplitude and frequency of the sound, habituation period, and other factors. Vessel traffic at a distance of 1.5 km from groups of *S. chinensis* significantly increased the rate of whistling immediately after a vessel moved through the area. Evidence from studies by (Van Parijis and Corkeron 2001) suggests that transiting vessels affect group cohesion in *S. chinensis* and that mother-calf pairs seem most disturbed. Ng and Leung (2003) observed that *S. chinensis* dove for longer periods in the presence of oncoming vessels or heavy vessel traffic. Behavioral response depended on the type and distance of the vessel; dolphins might flee, alter direction, or approach the vessel. Slow-moving vessels appeared not to cause immediate stress on the dolphin community, but fast-moving vessels, especially small power boats, often cause disruption of behavior and social life (Ng, and Leung 2003, Karczmarski et al. 1997).

Soil consolidation or densification, needed to stabilize reclaimed land prior to construction, is a basic component of hydraulic land reclamation. Densification generally involves dynamic (impact) or vibration and this may contribute to overall underwater sound levels during construction. Several techniques have been used in land reclamation actions in East Asia, including dynamic compaction, vibroflotation and resonance compaction techniques (Kao 1998). In Taiwan, the vibroflotation technique is known as the Sand Compaction Pile Method and it uses a vibratory hammer with pipe pile (Moh et al, 1981). Information available at this point suggests that dynamic compaction will be used. The underwater sound levels generated from this activity are not well documented but, due to the extent of compaction needed, this should be investigated further.

4.4 Possible contaminant releases and accidental spills

Contaminants may be released from construction equipment, completed petrochemical plant operations, associated industrial facilities, and vessels supplying crude oil and transporting products. Releases may occur due to routine operations, such as wastewater discharges and fugitive air emissions, or accidental leaks and spills. Large petrochemical facilities have several thousand km of piping and leaks are inevitable. Contaminants may enter the coastal system directly through outfalls and surface runoff, via atmospheric release and deposition, groundwater, and as a result of breakdowns on the facility or vessels spills. Potential adverse consequences will depend on the toxicity (sensitivity) of the contaminant and, its fate and transport in the environment (exposure).   The impact of a major spill of oil or toxic products produced at this facility on the ETS population may be severe given the small population size, nearshore habitat use (sensu Reeves et al. 2008) and the nature of the nearshore habitat.

4.4.1 Operational releases

Refineries release numerous pollutants into the atmosphere including volatile hydrocarbons, sulphur and nitrogen oxides, hydrogen sulphide and other hazardous air pollutants. Ship activity at the harbor will also add sulfur dioxide, nitrogen dioxide, carbon monoxide, and hydrocarbons to air emissions. The facility is projected to produce 6.636 tons/yr sulphur oxides, 9332 tons/yr nitrogen oxides; 1,048 tons/yr total suspended particulates, and 3,169 tons/yr volatile organic compounds (Wang et al. 2007a). A number of metal contaminants (As, Mo, Ni, S, Se, V, and Zn.) are associated with airborne particulates from petrochemical plants (Bosco et al. 2005). These airborne pollutants will be deposited in the ETS habitat where they may impact dolphins directly or through their food webs. Since dolphins are air breathing mammals, inspiration is a potential problem, especially if they congregate around the facility to feed. Dolphins may not have a sense of smell and thus are be unlikely to avoid the odor that is associated with oil refineries. In the US, EPA estimates that half of all volatile organic compound emissions are fugitive emissions and these can cause a variety or respiratory ailments that impair lung function.

The operation of a refinery and petrochemical facility produces a variety of waste water streams, some of which contain contaminants that may be routinely released. Industrial and human waste water is estimated to be 73,598 m^3/day and surface runoff is estimated a 4,726 m^3/day (Wang et al. 2007a).   Some of the contaminants of concern include polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface-active substances, sulphides, naphthylenic acids and other chemicals. Depending upon the development of co-located chemical processing facilities, other potential contaminants may also be included. The uptake of a range of contaminants including petroleum hydrocarbons by *S. chinensis* has been documented from industrial areas in Hong Kong (Leung et al., 2005). Although state-of-the-art waste treatment can reduce potential concentrations it does not completely eliminate them and some, such as aromatic hydrocarbons and metals, are associated with pathological problems in fish and will enter the food web of *S. chinensis*. Pollutants may reduce forage prey fish stocks or increase their body burden of selected contaminants, and result in pathology. Lactating marine mammals can provide their calves with elevated and even toxic contaminant doses from their mobilized lipid stores that do not overtly impair adults. Studies with the bottlenose dolphin in Florida have demonstrated that females usually have lower levels due to the transfer of persistent organic pollutants to calves during gestation and lactation[22]. First born calves apparently receive the highest dose and suffer the greatest mortality[23].

In addition to bioaccumulating contaminants, endocrine disrupter compounds (EDCs) have also been linked to process water from land based petroleum refineries. Tollefsen et al. (2006) reported that refinery solid phase extracts of process water contains chemicals capable of inducing estrogenic effects and displacing natural sex steroid 17β-estradiol from the SBP/EDCs, mimic endogenous hormones, interfere with pharmacokinetics, or act by other mechanisms to impair reproduction. EDCs can reduce reproductive fitness, cause birth defects or cancer, and interfere with immune system function. Further work is needed to identify the bioreactive chemicals, but they appear to be partly resistant to biodegradation.

4.4.2 Accidental Spills

Accident releases may occur both from the facility and from ships bringing oil into the refinery or transporting product from the facility. Increasing tanker traffic increases the possibility of an oil spill. The relative severity of ecological impacts from accidental oil spills depends on the volume and nature of the oil, the type and amount of other chemicals, such as dispersants, used, and the characteristics of the receiving ecosystem. Long-term studies of the *Exxon Valdez* oil spill in 1989 now conclude that there were significant impacts to killer whale (*Orcinus* o*rca*) pods in Price William Sound, at least one of which did not recover, and that the remaining whales have not yet met their recovery goals (Loughlin et al. 1996, *Exxon Valdez* Oil Spill Trustee Council 2009). Oil spill injury observations from the *Mega Borg* oil spill in the Gulf of Mexico indicated that bottlenose dolphins detected slick and denser mousse oil, avoided the mousse, but not the slick, thereby potentially exposing themselves to harmful oil chemicals (Smultea and Wursig 1995).

In the event of an oil spill, dolphins can be exposed to petroleum contaminants and possibly dispersants both internally and externally. Externally their body and skin can be exposed when they swim through oil or oil/dispersant mixtures. This can cause skin or and eye irritation and burns to the mucus membranes of the eyes and mouth which can

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[22] Assessment of Emerging Environmental Contaminants in Bottlenose Dolphins Jan 13, 2004 Magali Houde. http://sarasotadolphin.org/2004/01/13/assessment-of-emerging-environmental-contaminants-in-bottlenose-dolphins/
[23] Effects of Environmental Contaminants, Jan 08, 2004.Randall Wells. http://sarasotadolphin.org/2004/01/08/effects-of-environmental-contaminants/

result in an increased susceptibility to infection. Internally they can be exposed by swallowing oil, eating contaminated prey fish or inhaling volatile oil compounds. These exposures can cause respiratory or gastrointestinal problems, damage to major organs, or reproductive failure[24].

The presence of oil can also alter behavioral responses in ways that can result in injury to dolphins. According to the U.S. Marine Mammal Commission[25], oil spills can displace animals from important habitat, alter movement patterns, adversely affect social structure, alter prey availability and foraging patterns, and impact reproductive behavior. These changes in the behavior-ecology can be significant with a small population, especially if the oil persists in the region. Post-spill persistence of petroleum and petroleum breakdown products will affect long-term impacts.

Apparently both Arabian Light and Arabian Heavy oil types will be delivered by tanker to the refinery[26]. The surficial sediments in this project area are fine grain sand and mud. Of particular concern are the heavier crude oils and fractions of crude oils that can weather and settle to the bottom. Heavy crude oils have a higher probability of sinking over time, especially when mixed with sand from either beach stranding or surf zone mixing (Michel and Galt 1995) Spilled oil that does eventually sink poses a more difficult cleanup and may result in longer term impacts. The probability of a major oil spill is low, but the consequences may be very significant. A major spill of heavy crude that sinks may add to the potential barrier created by the facility, especially if it remains long enough to adversely impact benthic invertebrate communities that support the food web for many prey species. Given the tidal flats in this area, the areal extent of benthic impacts could be significant.

4.5 Vessel Strikes

As vessel traffic increases both during construction and facility operation, the potential exists for increased injury or mortality due to vessel strikes. In Hong Kong, the heavy vessel traffic has had an adverse impact on *S. chinensis* (Ng and Leung 2003). One study by Jefferson (2000) indicated that 2.8 percent of animals in a study had evidence of propeller cuts on their body and 12.5% of stranding specimens observed also had evidence of strikes by vessels. Studies during 1993 to 1998 suggested that 14% of all strandings were caused by boat strikes (Parsons and Jefferson, 2000; Parsons 2004) and studies during 1995 to 2004 found that of the 53% of the strandings were young-of-the-year and that the most commonly diagnose causes of death were net entanglement and vessel collisions (Jefferson et al. 2006).

Anthropogenic sound sources may exacerbate vessel strikes by interfering with hearing, especially during construction when ambient sound levels will be significantly increased.

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[24] NOAA Fisheries Service Fact Sheet. Impacts of Oil on Marine Mammals and Sea Turtles. 2009
[25] http://www.mmc.gov/ Deepwater Horizon Spill Impacts on Marine Mammals
26 Personal communication Horace Nian-Tzu Wu, Hydraulic and Ocean Engineering Dept. Sinotech Engineering Consultants Ltd.

Post construction vessel traffic will also introduce interference in the vicinity of the channel area. These synergistic interactions are difficult to predict, but could increase potential vessel strikes.

5.0 Conclusion

Building a petrochemical facility on reclaimed land at the proposed Changhua site will create unavoidable adverse impacts for the ETS population. Due to the small size and endangered status of the ETS population, all five risk factors considered in this scoping review may individually result in significant adverse impacts. Since the project impact on the ETS population is the joint consequence of all these, and perhaps additional factors, the cumulative and synergistic impacts of the proposed construction present a serious risk of population extirpation. The greatest risk factor may be population fragmentation resulting from the potential synergistic impact of barrier creation and anthropogenic sound generation.

To assure the preservation of the ETS population, the facility should not be built at this site or anywhere else within the limited ETS population range. A recent examination of population trends confirms the highly vulnerable status of the ETS *S. chinensis* population[27] and justifies a precautionary approach to ensure that this project does not become the tipping point for local extinction of this population.

Stopping or relocating this project outside the ETS population range will avoid additional potential impacts, but will not solve the underlying and fundamental problems threatening coastal ecosystems in Taiwan. The absence of sound strategic regional land use planning to protect the environment or conserve natural resources plus the failure to adhere to and/or enforce existing environmental and resource protection statutes are responsible for continued decline in ecosystem resiliency. Piecemeal environmental assessment and mitigation within the context of minimally controlled industrial development, which considers impacts on a project by project basis rather than a holistic view of the coastal ecosystem, results in treating symptoms rather than root causes. Not addressing root causes is a prescription for failure to protect Taiwan's coastal ecosystems.

If the decision is made to build the petrochemical facility at this site despite the clear and credible evidence suggesting potential significant adverse environmental and natural resource impacts, an aggressive and adaptive mitigation program should be implemented to reduce those impacts that can be addressed to some extent. The implementation of mitigation measures should be required and funded as a condition of the permit to proceed. Mitigation performance should be independently and routinely monitored and the findings peer reviewed in order to provide valid data for adaptive management. Failure to tie required mitigation to the permit to build or operate all to frequently results

[27] 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 the Chinese coast. June 4-7, 2010, Nanjing, China

in unimplemented or 'cosmetic' mitigation projects. When adequate or independent monitoring based on valid criteria is not required, mitigation performance is unknown or inadequate. Although a decision to proceed with construction at this site would pose serious threats to the ETS population, failing to implement the best available adaptive mitigation measures, would be irresponsible.

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