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Harbour porpoise (*Phocoena phocoena*) conservation management: A dimensional approach

Rhian E. Jenkins *, Raymond D.H. Brown, Michael R. Phillips

Faculty of Applied Design and Engineering, Swansea Metropolitan University, Swansea, Wales SA1 6ED, UK

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ABSTRACT

Harbour porpoises *Phocoena phocoena* are protected under the Habitats and Species Directive (92/43/EEC) and listed as a priority species in the City and County of Swansea's Biodiversity Action Plan (BAP). Increased coastal pressures demand better governance and this study adopted a dimensional analysis to produce a local management framework for harbour porpoise populations. Having established basic behavioural dynamics and identified critical habitats, a coastal zone use model was developed. This highlighted porpoise and coastal user interaction from a species perspective. Evidence was determined from observations and published research, and an Environmental Risk Assessment (ERA) was undertaken. An estimation of consequence probability was determined and revealed that continued coastal use, without mitigation, is likely to have significant local impacts on porpoise populations. A strengths, weaknesses, opportunities and threats (SWOT) analysis and legislative appraisal highlighted potential opportunities and deficiencies. Mitigation refers principally to industry, fisheries and recreation and suggestions include flexible zoning; speed and vessel restrictions; engineering solutions to noise intrusion and fisheries monitoring. A mixture of formal and informal regulations is recommended, together with educational projects and industry-funded research opportunities.

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1. Introduction

Anthropogenic activities in coastal areas are threatening marine organisms at every trophic level. Coastal conservation is compounded by climatic and sea level fluctuations, over fishing, pollution and development demands [1–3]. The synergistic and cumulative effect of these factors means there is an urgent need to monitor species throughout the generic marine food chain [4]. Harbour porpoises *Phocoena phocoena* are the smallest and most commonly observed cetacean[1] in UK waters [5–7]. However in recent years, a general decline across its Northern Hemisphere range has prompted further cetacean and habitat-related research [8,9]. Coastal regions of South Wales, UK, are ideally located for the emergence of renewable energy sources and together with the recent revival of a mussel industry, all have to address environmental impacts [10,11]. Similarly, a burgeoning tourism trade, so reliant upon coastal and wildlife influences, is potentially threatening coastal ecosystems [12]. Prideaux [13] suggested that the mobile nature and temporal distribution of cetacea demands ecosystem management, underpinned by marine protection areas (MPAs), which concentrate on critical habitat. Not only can this style of management mitigate against potential threats, but it can protect those habitats upon which the target species' rely. The aim of this study was to produce a workable management framework with harbour porpoises central to that commitment. Given protection for this species under the Habitats and Species Directive (92/43/EEC), it was first necessary to demonstrate whether there was a need to manage porpoise populations in Swansea Bay (Fig. 1). This area is a busy port that handles commercial traffic as well as a small fishing fleet and with a growing tourism trade, maritime recreation is also increasing [14]. Available stranding data suggested potential conflict in this area but the mechanisms surrounding interaction and entanglement are not fully understood. Using a dimensional approach, a strategic management process was undertaken in order that problem recognition, mitigation and monitoring systems could be established [15–20].

Environmental management tools can be *assessment tools* such as strategic environmental assessment (SEA), which addresses socio–economic and ecological issues at a policy level, as well as environmental impact assessment (EIA), at a project level. However there are *delivery tools*, which incorporate activity controls (exclusion zones), best practice (technology) and capacity controls (charge limits). It has been stated that Integrated Coastal

*Corresponding author. Tel: +44 1792 481106; fax: +44 1792 651760.
E-mail addresses: rhian.jenkins@smu.ac.uk, rhianjenkins@btinternet.com (R.E. Jenkins), raymond.brown@smu.ac.uk (R.D. Brown), m.phillips@smu.ac.uk (M.R. Phillips).

[1] Collective noun for whales, dolphins and porpoises.

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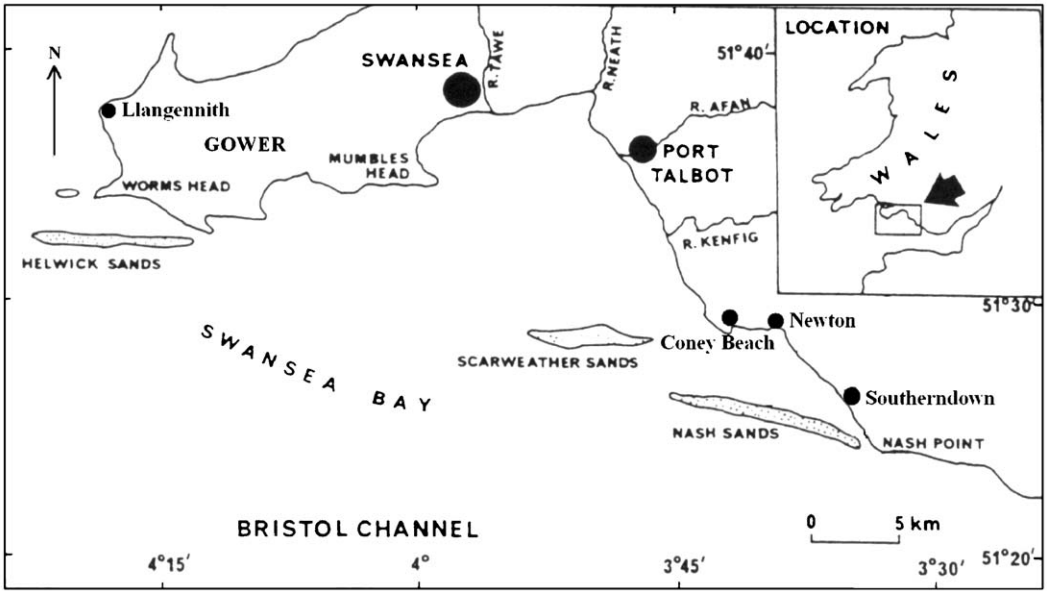

Fig. 1. Location of survey area.

Management (ICM) is a cyclic process of problem recognition, planning, implementation and monitoring [21]. This strategy can be applied to ecosystem management, although any proposed mitigating measures need to be thoroughly analysed in respect of technical and economic solutions [22].

2. Methodology

2.1. Legislative assessment

Governance of coastal seas and marine habitats is both complicated and bureaucratic, characterised by a multitude of legislation and guidelines, under which harbour porpoises and their habitats are seemingly protected. There are 16 UK relevant Government Acts, 20 European & International directives and conventions as well as conservation, shipping, pollution prevention and fisheries legislation, all of which apply to this coastal species and its habitat [23]. Yet harbour porpoises, amongst many others, still face a vast array of natural and anthropogenic-induced pressures that threaten their existence. Currently UK marine conservation has multiple layers of regulation, a voluntary approach, and sectoral management, which is currently neither effective nor integrated.

2.2. Dimensional approach

There are five dimensions to every problem [15]. These being:

- *Substantive dimension*—whether or not an activity for example is harmful and should be ceased, modified or some mitigating measure introduced.
- *Spatial dimension*—identification of problem boundaries and whether issues are local or widespread; whether local areas are affected by activities outside of the boundary limits, etc.
- *Temporal dimension*—identification of existing, recent or long-term problems; whether previous measures for an alternative problem may have inadvertently caused current situation.
- *Quantitative dimension*—whether the problem is caused by single or multiple causes and whether there could be a cumulative effect.
- *Qualitative dimension*—cultural and value assessment of marine systems to the community at large; effect of losing a valuable site or organism.

Within the context of porpoise populations, dimensional analysis was undertaken initially through assessing habitat dynamics and mortality rates. Identifying potential threats and levels of awareness was necessary (*substantive dimension)* together with those external developments that may influence the natural status quo. For example, problem boundaries were identified and interactions between the local system and adjacent areas (*spatial dimension*). Time factors, such as seasonality, future predications and stochastic changes were assessed (*temporal dimension*) and a *quantitative dimension* implied the generation of long-term datasets under different conditions. In order to identify at what stage an *issue* becomes a *problem*, the establishment of focus groups and stakeholder meetings was considered. The *qualitative dimension*, is perhaps most difficult to address given its subjectivity and considered socio-economic and environmental factors. Those associated with marine recreation and conservation, together with the mechanisms influencing policy, were identified.

2.2.1. Assessing population dynamics and critical habitat identification

Through a combination of vessel and shore surveys, together with stranding data evaluation, a resident population of harbour porpoises had previously been established [24]. By observing behavioural patterns, interpretations were made regarding feeding and/or breeding critical habitats. Responsive reactions to vessels were also examined during these investigations. A combination of *ad libitum*, *scan sampling* and *continuous sampling* [25,26] were used. During analysis however, only those encounters exceeding 15 min were considered. Further consideration of tidal state, currents, bathymetry, food sources and behavioural patterns would identify critical foraging, nursery and transient habitats.

2.2.2. Coastal user conflict

Using Ketchum's anthropogenic users of coastal zone model as a starting point [17], and considering other methodologies

[18–20], a model was derived, addressing interactions between harbour porpoises and coastal users. For the first time this looked at coastal usage problems from a harbour porpoise's perspective, rather than being anthropocentric in approach. Using Ketchum's six main categories (industrial and commercial; residential and recreation; food production; military and strategic; conservation; waste disposal) conflicts between coastal users and porpoise habitats were identified.

2.2.3. Environmental risk assessment (ERA)

As part of the spatial dimension, it was important to establish scientifically sound and realistic indicators which management and policy makers would find acceptable. Having proposed potential impacts from coastal users based upon observations during data collection and further justified from relevant published research, an ERA package was used to formally evaluate significant impacts. As a semi-qualitative analysis, it provided statistical weighting of probabilities, as well as a summary consequence matrix of magnitude and probability [27]. Following ERA's approach, impacts, consequences and magnitudes were detailed for each coastal use category identified. Furthermore, for each impact highlighted (positive and negative), consequences were acknowledged, while an estimation of magnitude was defined.

2.2.4. A strengths, weaknesses, opportunities and threats (SWOT) analysis and site-specific management issues

A SWOT analysis of coastal users was undertaken to highlight the type of local management system, potential economic activities and existing environmental threats. Although done for the entire survey area, such a methodology has the potential to be site-specific also.

3. Results

By considering all available datasets, it was possible to identify key areas around Swansea and Gower, which offered different habitat usages. These areas detailed in Table 1 show that five areas of porpoise usage were identified: *feeding*; *breeding*; *resting*; *socialising and migrating* corridors between critical habitats. Areas of potential conflict and dual usage were subsequently identified (Table 2).

Impacts for each critical habitat were considered. *Commercial and industrial* coastal zone usage for instance could potentially interfere with feeding, breeding, resting, socialising sites and along connecting habitat corridors. *Military and strategic* conversely, is generally confined to Carmarthen Bay (to the west) and therefore would more likely interfere with breeding, resting and socialising areas. In order to make analyses activity specific, anthropogenic activities applicable to the survey area were identified. An example of how residency and recreational sectors potentially affect critical habitats is given in Table 3. Rationale for each assessment was based on published data and survey observations, which further informed the ERA.

Following ERA's approach, impacts, consequences and magnitudes were detailed for each coastal use category. For example, impacts could refer to physical changes in water processes or ecosystem function and using ERA's categorisation as a guideline, four were subsequently identified:

1. Effects on water quality
2. Effects on benthic habitat
3. Accidental mortality
4. Habitat exclusion

For each impact highlighted (positive and negative), consequences were acknowledged. These could arise directly or

Table 1
Site comparisons: physical and observed differences [24].

	Zone 1: Mumbles	Zone 2: Oxwich	Zone 3: Port Eynon and Limekiln Point	Zone 4: Carmarthen Bay
Dynamic environment	Exposed to elements (SW)	Bay itself is sheltered but headland is exposed to SW	Especially Helwick Bank—most highly exposed sandbank to waves and tidal action in Wales	Sheltered inner Bay, southern portion exposed
Sediment	Muddy sand	Sand → gravel offshore	Sand → gravel offshore	Sandy
Mean depth at peak encounters	22.65 m	28.45 m	19.97 m	25.70 m
Highest tidal currents	HW-2, HW-1, HW+2, HW+3, HW+4~	No data	No data	HW-3, HW-2, HW +3
Peak encounters	HW+4, HW-2	HW, HW+1, HW-3	Data deficient. LW and HW	Data deficient. HW+1,
Boat activity	High	High	High	Low
Peak activity	January, May, August	August, November	May, August, November	May, August, October
Predominant Behaviour	Foraging	Socialising, resting and rearing	Transient and opportunistic feeding	Breeding and nursery area
Notes	Increase in circling behaviour as year progresses. Summer encounters negatively correlated with survey effort. Importance of 20 m contour	Increase in circling as year progresses. Sibling agonistic behaviour seen as well as parental teaching.	Dominant flood tide north of Helwick, ebb tide dominant to south—porpoise encounters positively correlated with dominant tidal direction. Importance of 20 m	Incidents of stranded individuals more prominent than other zones.

Table 2
Coastal user conflict.

Coastal uses	HP uses				
	Feeding	Breeding/Rearing	Resting	Socialising	Corridors
Commercial and industrial	■	■	■	■	■
Residency and recreation	■	■	■	■	■
Agriculture, aquaculture and fishing	■	■	■	■	■
Military and strategic		■	■	■	
Conservation	■	■	■	■	■

Table 3
Potential impact from coastal users.

Coastal uses	Harbour porpoise uses				
	Feeding	Breeding/Rearing	Resting	Socialising	Corridors
Residency					
Maritime quarter					
SA1					
Recreation					
Boating activities					
Sailing	▪		▪		▪
Jet ski	■	■	■	■	■
Water skiing	■	■	■	■	■
Canoeing			▪		▪
Power boating	■	■	■	■	■
RIB excursions	■	■	■	■	■
Water sports					
Wind surfing			▪		▪
Swimming					
Diving		▪			▪
Surfing					

Key: Impacts upon harbour porpoises from coastal users. Small potential benefit ▪; Small negative impact ▫, Large potential benefit, □; Large negative impact, ■.

Table 4
Evidence of interaction indicators.

Coastal uses	Evidence of interaction indicators
Residency	
Maritime quarter	• Infrastructure—existing and new developments
SA1	
Recreation	
Boating activities	
Sailing	• Noise disturbance and habitat exclusion
Jet ski	• Collisions
Water skiing	• Physiological impacts
Canoeing	
Power boating	
RIB Excursions	
Water sports	
Wind surfing	
Swimming	
Diving	
Surfing	

indirectly as a result of habitat conflict and could be short- or long-term in effect. Impact 4 (habitat exclusion) for instance had four identified consequences:

- Industrial noise disturbance
- Electromagnetic disruption
- Vessel noise disturbance
- Agonistic interactions

Estimation of magnitude was defined as severe, high, mild or negligible and evidence for reasoning and subsequent ranking was highlighted (Table 4). Previously users of this package have considered net impacts for a proposed development, having accounted for anticipated mitigation. In this case, many current and potential coastal users are considered, with harbour porpoises in mind, and at present, no mitigation is being initiated.

Each interaction indicator was considered in detail and observational evidence of potential impacts backed up by other literature. In the case of examples given in Tables 3 and 4, many authors have documented high impact activities such as jet skiing or power boating as causing harassment, fatalities and habitat exclusion during busy periods [28–31]. Vessel detection is far less (450 m) for a jet ski than it is for an inflatable (1 km) [28] and an erratic approach can pose considerable risks to juvenile mammals especially. All vessels have the potential to present a threat. Under sail, their approach can go largely undetected and particularly vulnerable are those resting or in transit further offshore.

The evidence presented for each coastal user interaction was used to assess potential consequences of porpoise and anthropogenic interaction. For each consequence, a semi-quantitative estimation of probability was proposed, followed by an assessment of relevance. In other words, would operations, developments, activities, etc affect a species and its habitat? Often it is the accumulation of various effects that undermine habitat integrity and as such, the ERA considers these cumulative impacts [27]. Probability is ranked as high, medium, low or negligible and relevance as yes or no. A worked example is given in Table 5.

In this example, consequence probability was based upon the ratio of boat type and porpoise interactions locally observed. 37% of interactions involved planing, high speed and erratically driven vessels; 37% were planing vessels, driven at moderate speeds on constant courses; 25% were displacement vessels and those at anchor, while 1% were canoes, sailing boats or yachts under sail. Therefore, there is a 37% chance that vessel disturbance will have a significant impact on porpoise exclusion and a 1% chance that it will be negligible. Having considered each impact and resultant consequence, ERA's software generated an automatic estimation of total risk along with a summary matrix (Table 6). This matrix provides a judgement on whether current and proposed developments and industries will have a significant impact on porpoise critical habitats. Overall, results showed that 16 occurred in the 'high' category and 19 in the 'medium' group. Therefore, the balance of probability is that continued coastal use in this area, without mitigation, is likely to have a significant effect on population. This model provided a guide for future management plans and decision-making.

Using these ERA results within the adopted coastal user framework, a SWOT analysis (*qualitative analysis*) identified management areas requiring attention and highlighted potential opportunities and mitigation. Results revealed evidence of a strong legislative and management-led system where economic opportunity from many sectors (industry, fisheries, tourism) in and around Swansea is evident. What is also apparent is despite much European legislation, and would-be protective mechanisms,

Table 5
Example of ERA report for impacts considered by habitat exclusion.

Impact no. 4	**Impact: Habitat exclusion**		
Impact explanation: Habitat exclusion can occur as a result of noise disturbance, electromagnetic disturbance or territorial interactions with conspecifics			
Consequence no. 3:	**Vessel disturbance (noise)**		
Magnitude:	**High**		
All vessels have the potential to disturb but some are more problematic than others. Small recreational craft, emitting high frequency noises have greatest potential to disrupt and exclude from critical habitats. In key resting and feeding habitats, high-speed planing vessels can potentially change population densities (area displacement or long-term health impacts if access to prey is continuously disrupted).			
Probability:	**High**		
Marine tourists and recreational boat users are increasing, which together with the local fishing fleet, frequently come into contact with feeding, resting and socialising porpoises. Swansea Bay Strategy Consulting (White Young Green Ltd, 2007) is proposing a new marine park and additional trips to and from Mumbles, promoting further boat-based recreation			
Relevance:	**Yes**	**Risk:**	**High**
Indirect effect on other coastal users and fish spawning grounds			
Estimation of consequence probability for each magnitude:			
Severe	Moderate	Mild	Negligible
0.37	0.37	0.25	0.01

Table 6
Count matrix for all relevant consequences.

Based on consequence magnitude and probability ratings:				
	Consequence			
Probability	Severe	High	Mild	Negligible
High	6	8	2	0
Medium	0	9	9	1
Low	0	2	6	5
Negligible	0	0	0	0
Severe 0.12	High 0.51	Mild 0.33	Negligible 0.04	

Table 7
Survey area relevant management issues [32,33].

Zones	Categories	Specific issues
Worm's Head/ Carmarthen Bay	Coastal processes	• Sediment movement—dune erosion and aggregate dredging at Helwick Bank
	Natural environment	• Water quality—discharge of sewage from outfalls at Overton and Oxwich • Statutory designations—SAC, SSSI, NNR and AONB. Non-statutory-Heritage Coast
Breeding and nursery area	Human and built environment	• Recreational sport: Sub aqua and wildlife tourism (boat-based) • Boat and shore angling. • Conflicts between recreational users from other zones • Aggregate dredging
	Coastal defences	• No relevant issues identified
	Development	• Development unlikely

there are many environmental threats impacting upon marine habitats.

A final site-specific analysis considered each zone and relevant issue, as previously highlighted by local Shoreline Management Plans (SMPs), while considering the porpoise critical habitats proposed (Table 7). This final analysis allowed for specific conflicts to be related to porpoises at an ecosystem level. Zone 4 (Table 4) had been identified as a breeding and nursery area and therefore habitat degradation through noise disturbance should be addressed.

4. Conclusions

Three key impacting categories were identified in the coastal user assessment, that is, *industry* (construction and aggregate dredging, and renewable energy), *fisheries* and *tourism/recreation*. Relevant mitigating procedures (*substantive dimension*) were considered (*Delivery tools*) alongside voluntary codes of conduct and education, both of which permeate each category. Where applicable, piling restrictions, water quality monitoring and speed or seasonal restrictions are advocated. Easier access to this data was also highlighted as a recommendation and it is recognised that there is much work to be done to improve relations with some stakeholder groups. Open-access to an environment where the multiplicity of activities generates much conflict, gaining widespread community support is vital for any conservation efforts. Globally there is a confusing array of formal regulations, the interpretation and enforcement of which are unsatisfactorily policed. This study has identified a resident population of harbour porpoises within the survey area and potential areas of critical habitat have been determined. To give due cognizance to existing protective legislation, however, regular and constant effort surveying must be continued so that baseline information provided by this work can be enhanced.

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