THEME SECTION

Role of scavengers in marine ecosystems

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CONTENTS

Introduction

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Although organisms from all phyla and all marine habitats consume dead carrion, trophic transfer of scavenged material, and processes associated with this transfer, are poorly understood (Britton & Morton 1994). The death of mobile consumers (such as fish and whales) leads to nutrient and energy transfer across ecosystem boundaries (Payne & Moore 2006) and substantial carrion subsidies can increase secondary productivity (Baxter et al. 2004, Catchpole et al. 2006, Payne & Moore 2006). Therefore, understanding the utilisation of dead biomass by scavengers will provide insights into the trophic transfer of nutrients and pollutants, and into carbon cycling, distribution and sequestration in the oceans.

There is now a considerable body of literature concerning scavenger biology, as well as on the use of

baited cameras, across a wide range of disciplines (coral reef management, deep-sea biology, neurobiology, hydrodynamics, and forensic science). In this Theme Section (TS) we intend to advance the field of marine scavenger biology by bringing together current expertise to discuss future research avenues, encourage collaboration, identify research areas in need of additional attention, compare techniques, and essentially spark debate.

Baited cameras. Marine scavengers are defined by Britton & Morton (1994) as organisms which are 'able to detect carrion, usually by either distance or touch chemoreception, or both, deliberating to move toward it, and eventually consume either part or all of it'. The exploitation of this behaviour has enabled fishers and scientists to use bait to harvest marine scavengers, and to obtain information on behaviour, densities, distribution and life history. Baited cameras use bait to attract organisms into the field of view where still images or video can be recorded at pre-set intervals. Baited cameras have been used to assess marine biodiversity and organism abundance, particularly in the deep-ocean, since the late 1960s (Bailey et al. 2007, this TS), but are now increasingly used in shallow water habitats, such as Marine Protected Areas, for more applied purposes such as fisheries assessment and biodiversity surveys (Ellis & Demartini 1995, Cappo et al. 2004, Morrison & Carbines 2006, Watson et al. 2007). Malcolm et al. (2007, this TS) present a wide-scale baited video camera survey of spatial differences and temporal changes in the diversity of temperate reef-fish assemblages from 3 marine parks over 5 years. Fish assemblages were found to vary within and between marine parks, with time playing a less important role than spatial separation in structuring fish assemblages. Malcolm et al. (2007) concluded that a network of marine parks is therefore required to allow for the spatial variation in the fish assemblages observed. Cappo et al. (2007, this TS) identified spatially separated vertebrate communities in lagoon and inter-reef waters of the Great Barrier Marine Park, Australia. The study extended over 14° of latitude and the entire shelf, and identified 347 species of osteichthyans, chondrichthyans, and sea snakes. Nine vertebrate communities, made up of 17 spatially adjacent groups were identified, with community boundaries strongly correlated with oceanography and habitat type. Harvey et al. (2007, this TS) found that baited camera systems (compared to unbaited) had less variability when replicated, allowing greater statistical power to discriminate spatially distributed temperate and tropical shallow fish assemblages. In addition, the baited cameras were found to attract increased numbers of predatory and scavenging species, without decreasing the number of other

trophic groups present, such as omnivorous and herbivorous fish species. Shallow baited-camera studies in pelagic habitats are rare; however, Heagney et al. (2007, this TS) have used mid-water baited video to assess pelagic fish assemblages off the east coast of Australia. In agreement with the benthic baited camera studies Heagney et al. (2007) have also found regional fish communities, with current speed having the greatest influence on assemblage structure.

The main advantages of baited camera systems are that they are non-destructive, photograph organisms *in situ* and are extremely efficient in their use of ship-time, i.e. they are generally autonomous, independent of the vessel and can be pre-programmed and left on the seabed. However, as with any sampling method, there are biases associated with baited cameras. The contribution by Bailey et al. (2007) introduces and reviews the advantages and use of baited cameras in deep-water environments, outlining sampling biases, and highlighting how baited camera-derived data compare with data obtained using other survey methods. Robust and realistic models are needed to predict local abundances of scavengers attracted to baited cameras, with most of the work to date being focused on the abyssal grenadier, *Coryphaenoides armatus* (Hector, 1875). Farnsworth et al. (2007, this TS) assess baited camera abundance-estimating techniques and provide an alternative stochastic model allowing quantification of the precision of such abundance estimates for *C. armatus*. As well as sampling bias and the currently limited abundance-estimate models, baited cameras can also be obtrusive and can produce artefacts within the data obtained (Jamieson et al. 2006). Raymond & Widder (2007, this TS) demonstrate that the spectral quality (white, red and far-red) of the light used to illuminate video sequences can affect the behaviour of the sablefish *Anoplopoma fimbria* (Pallas, 1814) more than another species, the pacific grenadier *C. acrolepis* (Bean, 1884) at a baited camera. Interestingly, the differences in behaviour between the 2 species are attributed to the differences in retinal spectral sensitivity associated with differences in life histories.

Anthropogenic impacts on scavengers. Scavenger ecology is also relevant to the understanding of anthropogenic impacts on the oceans. In particular, recent research has revealed the positive effect of fishery discards on seabird and marine benthic scavenger populations (e.g. Camphuysen et al. 1995, Garthe et al. 1996, Catchpole et al. 2006). It is estimated that a biomass equivalent to approximately 27% of global fish catches (Alverson et al. 1994) is discarded by fishery fleets and that seabirds consume 50% of that discarded material (Jennings & Kaiser 1998). However, surface-feeding seabirds are selec-

tive in the items they consume which can directly affect the type and supply of offal available to benthic scavengers on the sea floor below (Furness et al. 2007, this TS). Debate continues as to whether benthic scavenger populations mirror the observed increases in seabird populations, and it has been suggested that fisheries discards can only sustain benthic carnivores for approximately 3 d yr^{-1} (Kaiser & Hiddink 2007, this TS). The anthropogenic impact of fisheries is, however, no longer the only risk to the marine environment. Increased carbon dioxide within our atmosphere has the potential to alter the chemistry of the oceans, and there are prospective plans to store excess carbon dioxide in the deep ocean. To address this issue Barry & Drazen (2007, this TS) studied the reaction of several caged deep-sea scavengers to episodic flushes with CO_2 rich water. The survival of caged marine scavengers varied, but interestingly all *Coryphaenoides armatus* perished, potentially as a result of cage-related stress. Macrourids are a dominant abyssal scavenger and a lack of tolerance to stresses that will accompany expected future changes in ocean chemistry are of major concern.

The way forward. This TS on the role of scavengers in marine ecosystems has brought authors from several fields of scavenger ecology together into the same discussion forum. Most importantly it has illustrated that scavengers can inform us about our own anthropogenic impacts on the oceans, and that baited cameras are an effective survey tool which are able to distinguish scavenging community assemblages on several scales. In addition, it has emphasised several research areas which require future attention. Models currently used in deep-sea research require improvement to increase accuracy and allow multi-species applicability; while models for abundance estimation in shallow marine environments need to be formulated. The key to enabling accurate abundance-estimation techniques and improving our general understanding of scavenger ecology in the marine environment is a fuller comprehension of odour-plume dynamics and scavenger response to odour. Hopefully these research areas will progress as technology advances and current research agendas move forward to address common research requirements within the field of scavenger ecology.

LITERATURE CITED

Alverson DL, Freeberg HH, Murawski SA, Pope JG (1994) A global assessment of fisheries bycatch and discards. FAO Fish Tech Pap 339, FAO, Rome

Bailey DM, King NJ, Priede IG (2007) Cameras and carcasses: historical and current methods for using artificial food falls to study deep-water animals. Mar Ecol Prog Ser 350: 179–191

Barry JP, Drazen JC (2007) Response of deep-sea scavengers to ocean acidification and the odor from a dead grenadier. Mar Ecol Prog Ser 350:193–207

Baxter CV, Fausch KD, Murakami M, Chapman PL (2004) Fish invasion restructures stream and forest food webs by interrupting reciprocal prey subsidies. Ecology 85: 2656–2663

Britton JC, Morton B (1994) Marine carrion and scavengers. In: Oceanogr Mar Biol Annu Rev 32:369–434

Camphuysen CJ, Calvo B, Durinck J, Ensor K and 8 others (1995) Consumption of discards by seabirds in the North Sea. Final report EC DG XIV research contract BIOECO/(93/10). Netherlands Institute for Sea Research (NIOZ), Den Burg

Cappo M, Speare P, De'ath G (2004) Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. J Exp Mar Biol Ecol 302:123–152

Cappo M, De'ath G, Speare P (2007) Inter-reef vertebrate communities of the Great Barrier Reef Marine Park determined by baited remote underwater video stations. Mar Ecol Prog Ser 350:209–221

Catchpole TL, Frid CLJ, Gray TS (2006) Importance of discards from the English *Nephrops norvegicus* fishery in the North Sea to marine scavengers. Mar Ecol Prog Ser 313: 215–226

Ellis DM, Demartini EE (1995) Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. Fish Bull (Wash DC) 93: 67–77

Farnsworth KD, Thygesen UH, Ditlevsen S, King NJ (2007) How to estimate scavenger fish abundance using baited camera data. Mar Ecol Prog Ser 350:223–234

Furness RW, Edwards AE, Oro D (2007) Influence of management practices and of scavenging seabirds on availability of fisheries discards to benthic scavengers. Mar Ecol Prog Ser 350:235–244

Garthe S, Camphuysen CJ, Furness RW (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar Ecol Prog Ser 136: 1–3

Harvey ES, Cappo M, Butler JJ, Hall N, Kendrick GA (2007) Bait attraction affects the performance of remote underwater video stations in assessment of demersal fish community structure. Mar Ecol Prog Ser 350:245–254

Heagney EC, Lynch TP, Babcock RC, Suthers IM (2007) Pelagic fish assemblages assessed using mid-water baited video: standardising fish counts using bait plume size. Mar Ecol Prog Ser 350:255–266

Jamieson AJ, Bailey DM, Wagner HJ, Bagley PM, Priede IG (2006) Behavioural responses to structures on the seafloor by the deep-sea fish *Coryphaenoides armatus*: implications for the use of baited landers. Deep-Sea Res I 53: 1157–1166

Jennings S, Kaiser M (1998) The effects of fishing on marine ecosystems. Adv Mar Biol 34:201–352

Kaiser MJ, Hiddink JG (2007) Food subsidies from fisheries to continental shelf benthic scavengers. Mar Ecol Prog Ser 350:267–276

Malcolm HA, Gladstone W, Lindfield S, Wraith J, Lynch TP (2007) Spatial and temporal variation in reef fish assemblages of marine parks in New South Wales, Australia—baited video observations. Mar Ecol Prog Ser 350: 277–290

Morrison M, Carbines G (2006) Estimating the abundance and size structure of an estuarine population of the sparid *Pagrus auratus*, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fish Res 82:150–161

Payne LX, Moore JW (2006) Mobile scavengers create hotspots of freshwater productivity. Oikos 115:69–80

Raymond EH, Widder EA (2007) Behavioral responses of two deep-sea fish species to red, far-red, and white light. Mar Ecol Prog Ser 350:291–298

Watson DL, Harvey ES, Kendrick GA, Nardi K, Anderson MJ (2007) Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone. Mar Biol 152:1197–1206