

## COMMENT

## Marine nurseries and effective juvenile habitats: an alternative view

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The recent paper by Dahlgren et al. (2006), which builds on the earlier paper of Beck et al. (2001), proposes a classification system to identify important marine nursery habitats to aid in directing future research and to provide managers with a tool for the protection of important habitats. This work is important in recognising the need for a clearer nursery ground definition, and particularly in emphasising that the value of a nursery ground goes beyond the abundance or density of juveniles it supports (Beck et al. 2001, Sheaves & Molony 2001, Dahlgren et al. 2006). However, we believe that this approach is oversimplistic and does not account for many key aspects of nursery ground value. In particular, the approach focuses solely on one aspect of nursery ground function, the provision of a physical area of habitat occupied by juveniles, and one measure of importance, the proportion of individuals contributed by a nursery ground. Consequently, the nursery ground concept of Dahlgren et al. (2006) fails to (1) identify and account for the effects of scale, (2) recognise the importance of complexity and connectivity, (3) recognise the importance of ecosystems, resources and processes in supporting juveniles, and (4) recognise that the value of a nursery ground is a function of the reproductive output of individuals from the nursery and not just the numbers of individuals it provides.

**Reproductive output, not numbers of recruits.** Dahlgren et al. (2006), and Beck et al. (2001) before them, measured the value of nursery grounds in terms of numbers contributed to adult populations, either the average number of individuals per unit area (Beck et al. 2001) or the proportion of individuals (Dahlgren et al. 2006). This approach relates to the value of a nursery from a purely exploitive, short-term, fisheries perspective; it does not recognise that—in an evolutionary, ecological and a sustainable fisheries sense—it is the contribution to the production of succeeding generations that determines real nursery-ground value.

Through its effect on size and growth, the quality of a juvenile habitat can have a large influence on the lifetime reproductive output of an individual (Chigbu & Sibley 1994, Sedinger et al. 1995). Consequently, individuals from some habitats will be more fecund than those from others, so that any classification of the importance of habitats based only on the number of individuals recruiting to adult populations is likely to be invalid and misleading.

**Spatial scale.** While Dahlgren et al. (2006) point out some of the shortcomings of Beck et al. (2001), which can lead to overlooking important habitats, they fail to clearly identify what they mean by 'habitat'. Dahlgren et al. (2006) use 2 examples; one of fresh and brackish 'habitats' within 1 river system, the other of structural 'habitats' such as sand, seagrass and hard bottom. Both examples focus on aggregations of all structural units of particular types within a circumscribed area. However, it is unclear how far beyond this scale the concept is likely to be applicable. In the past, the concept of 'nursery grounds' has been discussed at a myriad of scales; a single type of habitat structure (e.g. mangrove or seagrass), a single geographic unit (e.g. a reef or an estuary), an aggregate of units (e.g. all the reefs in a reef complex, all seagrass beds in a bay), all units of one type (e.g. algal beds or estuaries in general). However, the importance, scope and meaning of 'nursery ground' all vary between scales. Additionally, the ability to unambiguously identify contributions and allocate them to particular habitat units differs between scales, as do the techniques available for determining nursery ground contribution. Without a clear definition of the range of scales at which the concept is applicable, the scales at which managers should apply the concepts of Dahlgren et al. (2006) are ambiguous.

Scale becomes more difficult to deal with when habitats are considered at more than a species-by-species level. Different members of a species complex characteristically use different habitat areas (La Mesa et al.

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2002). Moreover, while some species use particular habitats within an area as 'nurseries', for others nursery ground value is derived from the whole area (Aiken et al. 2002); in essence, nursery ground provision needs to be considered at different scales for different species. Defining the boundaries of nursery units is even more difficult where fish that use 1 principal habitat migrate through other habitats as a necessary part of their lives (Lindholm et al. 1997, Sheaves 2005).

The question of scale is important from another perspective. The importance of a nursery habitat will depend on the specific management objectives being addressed. Habitats that make small contributions to the sustainability of a particular stock or population may still have high conservation significance for that species at a local scale (e.g. may be important for a localised fishery but irrelevant for the species as a whole). An organisation charged with the responsibility of managing a large-scale multispecies fishery will obviously have different views on the value of a particular habitat than, for example, a regional catchment authority or local council aiming to protect a local recreational fishery or manage coastal development. However, the rigid classification system of Dahlgren et al. (2006) fails to accommodate different management objectives and fails to provide managers with information about the relative importance of a range of habitats at particular scales. In addition, it fails to provide any information about what particular features of a habitat or ecosystem make it valuable as a nursery.

**Connectivity and complexity.** The concentration of Dahlgren et al. (2006) on a single habitat as the unit of nursery-ground value is oversimplistic. In many cases, the situation is more complex, with many habitat types or habitat areas contributing to support juvenile nutrition and provide refuge from predation (Dorenbosch et al. 2004a, Niklitschek & Secor 2005, Sheaves 2005) Where this occurs, untangling the contribution of the various constituents of the mosaic could prove very difficult. The effectiveness of habitats may be additive, with many different habitats utilised over time and space (Hernandez et al. 2001, Pederson & Peterson 2002, Niklitschek & Secor 2005), making identification of the exact contribution of each, and unambiguously quantifying the importance of a particular habitat, fraught with difficulties. For instance, many juvenile fish are migratory (Dorenbosch et al. 2004b, Heupel & Simpfendorfer 2005), so even where a principal 'important' habitat can be identified, areas beyond its bounds may be important for survival (Lindholm et al. 1997), even though their importance appears to be low. Additionally, under the scheme of Dahlgren et al. (2006), areas with lower than average contribution would be given low management priority, even though

their additive contribution to adult populations may be substantial. In other cases, particular critical habitats may be obligate but used for only a short period of time. Such habitats may be difficult to detect and so easily missed in any 'habitat inventory', leading to their critical input being overlooked.

**Process-based nursery value.** The focus 'habitats' has a more fundamental difficulty: it ignores the fact that many nursery-ground values are process-based and so not necessarily a feature of a habitat unit. Indeed, much of the nursery-ground literature is concerned with the role of nursery grounds in providing nutrition and/or refuge from predation. From a process point of view, it may well be that the fact that a nursery ground provides more individuals (total or per unit area) to adult populations is simply a function of ecological bottlenecks controlling the supply of recruits to the various potential nursery grounds (Brown et al. 2004) or the supply of juveniles from the potential nursery grounds to adult populations (Sheaves & Molony 2000). Moreover, these events may not occur in the identified nursery ground, but their outcome may give the impression of a nursery ground being important. For example, physical conditions (Peebles 2002), the supply of food (Kingsford & Suthers 1996, North 2002) and abundant predators (MacGregor & Houde 1996) at the estuary/ocean interface may influence the supply of larvae to different nursery grounds. In this case, a simple accounting of contributions of nurseries may miss the point that it is the process of predation at particular hot spots that needs to be understood and factors likely to affect the level of predation that need to be managed. These processes, or the habitats where they occur, would not be identified as important, because techniques, such as natural markers (Gillanders et al. 2003), used for identifying the contribution of habitats, provide no information on the contribution of processes (eg. lack of predation), and the transient nature of occupation of predation hot spots would be too brief to leave a detectable signature. A parallel situation exists where a large proportion of the nutrition utilised in one habitat is donated from primary production in another habitat (Connolly et al. 2005). Again, in such a situation protecting the 'nursery habitat' ignores the fact that often a mosaic of habitats contribute in different ways to nursery-ground value (Sheaves 2005).

**Ecosystem focus.** While it is true that managers are faced with a need to prioritise distribution of funds and effort, and that appropriate categorisation can aid decision making processes, reducing inherently complex functions to simple categories is risky. Breaking complex systems into simpler units can provide insights, but it is dangerous to apply such piece-by-piece understanding in isolation from the complexity.

Ignoring complexity limits understanding of the way individual responses are modified by interactions with other components in the system and fails to adequately recognise the full range of values of a range of habitats or processes that may be critical in the functioning of juvenile nurseries. Consequently, a single-species, habitat-focussed approach has limited application to the management of marine systems. Around the globe, management organisations recognise the complexity of links between species, habitats and processes, which combine to support and drive ecosystems. Management objectives have shifted to a holistic, ecosystem approach (Corkeron 2006), where the focus is on understanding these linkages and processes (McKinnon et al. 2003). This shift in fisheries management focus has been driven by the inability of reductionist models to provide information capable of arresting the downward trend in fish stocks. In this context, the approaches of Beck et al. (2001) and Dahlgren et al. (2006) have limited management value. Rather than providing a useful tool to describe and understand complex systems, an approach which simply classifies a habitat as either important or not important ignores the inherent complexity and the very processes which contribute to the value and functioning of these systems. The approach of applying a rigid and overly simplistic 'recipe book' classification of complex and dynamic systems may lead to a failure to adequately recognise and understand critical links and processes which support marine nurseries.

**Dangers in the 'habitat valuing' approach.** Because our understanding of the processes supporting nursery function is relatively poor, there are dangers in the approach of Dahlgren et al. (2006). Although we have a sound understanding of the fauna of some habitats, and some of the processes supporting nursery-ground function, the fauna of many habitats and many potentially influential processes are poorly understood (Kamenos et al. 2004, Baker & Sheaves 2005). Any categorisation based on valuing habitats presents the danger of ranking well-studied habitats more highly than those that are poorly understood, with the value of unstudied nursery grounds being inevitably overlooked. Consequently, it is important to consider the advantage of a simple decision-making tool in the light of the dangers of ignoring poorly studied but crucial habitats. The risk is that once it is determined which habitats are 'important' nurseries, there will be a strong tendency for the focus to shift to managing those habitats, rather than evaluating the classification more extensively. This is particularly dangerous in resource-poor countries, exactly those where specific information is likely to be limited. A lack of specific knowledge, matched with a paucity of resources, means a high probability of categorisation being based

on understanding extrapolated from elsewhere, providing a high potential for erroneous nursery habitat categorisation (Linnane et al. 2001). Consequently, unlike Dahlgren et al. (2006), who believe that the ease of calculating their measure of nursery-ground value makes it particularly valuable for managers in developing countries, we believe that this is exactly the situation where a rigid categorical approach is most dangerous. At a more basic level, we need to question the rationale behind ranking nursery grounds, or effective juvenile habitat, in the face of declining fish populations. If current nursery habitats in total do not contribute sufficient adults to sustain current fish population sizes, then any ranking of nursery habitats only provides a means for prioritising the further reduction in overall nursery ground outputs.

**Conclusions.** Because of its narrow focus, the effective juvenile habitat concept of Dahlgren et al. (2006) fails to (1) account for the effects of scale, complexity and connectivity, (2) include the crucial resources and processes supporting juveniles, or (3) recognise that nursery ground value cannot just be measured as a numeric contribution to the adult stock, but must include accounting of the contribution to future generations. While protecting habitats has merit, the corollary is that there are habitats that can be allowed to degrade. The explicit assumption is that the preserved areas are 'keystone' habitats of particular importance; the implicit assumption is that others are not. There is a basic philosophical problem in considering habitats as individual, independent entities that can be excised from each other and be preserved or allowed to degrade with independent consequences. The deeply ingrained paradigm that 'all nature is connected', the understanding from chaos theory that small changes can produce widely divergent outcomes (Bissonette 1997), and our growing understanding of connectivity, habitat mosaics and the importance of understanding complexity, mean that this is a fraught position. Even if we can in some way identify habitats that are 'of more value' and 'more worth saving', the basic complexity of natural systems means we usually have little clear idea of the likely consequences of concentrating on those habitats at the expense of others, for those high value habitats or for the species we are trying to protect.

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