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Estimating the recreational harvest of fish from a nearshore designed artificial reef using a pragmatic approach

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ABSTRACT

Designed artificial reefs (ARs) are deployed for various purposes including the enhancement of recreational fisheries. The ability to assess recreational harvest is important for determining the effectiveness of AR deployments. Harvest estimation at AR fisheries pose many logistical and budgetary challenges. We present a pragmatic approach to estimate harvest at an AR off coastal Sydney, Australia, that combines existing datasets and a cost-effective sampling design from two different time periods. Fishing effort data collected from June 2013 to May 2014 were derived directly from digital images of the AR and were validated by direct observation. Multiple datasets were then integrated to obtain a list of taxa that are harvested by recreational fishers within the AR area. Data from a series of probability-based surveys conducted prior to the deployment of the AR from March 2007 to February 2009 were used to obtain estimates of harvest rates for these taxa. Harvest at the reef was estimated by multiplying fishing effort and these harvest rates together. Total annual recreational harvest from the AR during June 2013–May 2014 was estimated to be 1016 ± 82 fish by number, 700 ± 59 kg of fish by weight, and 12,504 kg per km^2. Standardized harvest at the Sydney AR was relatively high (2.3–43.6 times larger) compared to other fishery areas from which the fishable area is known. Harvest at the AR was dominated by 6 functional groups (ambush predators, leatherjackets, large to medium pelagic fish, small pelagic fish, medium demersal predators and large demersal predators), which accounted for 92% of the total annual harvest by number, and 95% of the total annual harvest by weight. Comparisons of standardized harvest between the Sydney AR and other fishery areas revealed two distinct groups, a) the AR and Swansea channel, a marine-dominated entrance to a large estuary, and b) all other fishery areas. The use of existing datasets from a previous time period to represent current conditions in a fishery can be subject to potential bias since harvest composition and harvest rates were calculated using data collected prior to the implementation of the AR. However, this pragmatic approach may be the only viable option when the implementation of probability-based survey methods is logistically complex and prohibitively costly.

Future studies attempting to estimate harvest at small, discrete AR fisheries located near large population centers should therefore consider an integrated methodology that combines existing datasets and cost-effective sampling designs.

1. Introduction

Recreational fishing is a popular leisure activity worldwide and is known to have substantial biological impacts, and high economic and social values (Henry and Lyle, 2003). The contribution of recreational fish harvest was estimated to be about 12% of the total global fish harvest (Cooke and Cowx, 2004). It has been estimated that about 11.5% of the global population participates in some form of

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recreational fishing activity (Cooke and Cowx, 2004; Arlinghaus and Cooke, 2009). In Australia, the 2000–01 National Recreational and Indigenous Fishing Survey (NRIFS) estimated that about 3.36 million residents aged 5 years and older had participated at least once in recreational fishing during the annual survey period (Henry and Lyle, 2003). The number of recreational fishers residing within New South Wales (NSW) was estimated to be about 999,000 and these fishers undertook about 7.67 million fishing events (Henry and Lyle, 2003). This equates to a participation rate of 17.1% in NSW compared to 19.5% nationally. The NRIFS also found that the majority of the recreational fishers within NSW resided in the Sydney area (about 48%) and that more than 40% of their fishing events occurred in the coastal marine environment (Henry and Lyle, 2003).

Artificial reefs have been deployed worldwide to create recreational fishing opportunities, or to enhance and restore degraded habitats (Bohnsack and Sutherland, 1985; Baine, 2001). These artificial reefs are believed to provide many benefits to fish populations and fisheries in their immediate vicinity (Bohnsack and Sutherland, 1985; Fabi and Fiorentini, 1994; Claisse et al., 2014; Ajemian et al., 2015; Scott et al., 2015). These benefits include: reducing fishing pressure on nearby natural reefs and mitigating localized rates of fishing-related mortality (Pickering and Whitmarsh, 1997; Zalmon et al., 2002; Cresson et al., 2014); providing a food source and shelter in an area where no reef habitat had previously existed (Fabi and Fiorentini, 1994; Claisse et al., 2014; Ajemian et al., 2015; Scott et al., 2015); and increasing fish density and biomass in the vicinity of the artificial reef that in turn leads to increases in catch yields (Bohnsack and Sutherland, 1985; Fabi and Fiorentini, 1994; Carr and Hixon, 1997; Santos and Monteiro, 1998; Zalmon et al., 2002; Whitmarsh et al., 2008; Bortone et al., 2011; Leitão, 2013). Whether artificial reefs actually enhance the production of fish biomass, or simply attract and aggregate fish leading to an increased risk of overfishing, is an ongoing debate (Bohnsack and Sutherland, 1985; Solonsky, 1985; Bohnsack, 1989; Carr and Hixon, 1997; Folpp et al., 2013; Smith et al., 2015).

In NSW, designed artificial reefs have been deployed in both estuarine and coastal marine areas for the primary purpose of recreational fisheries enhancement (Folpp et al., 2011; Folpp et al., 2013; Lowry and Folpp, 2014; Lowry et al., 2014). These man-made structures are purposely built for providing bottom structure in selected areas of the marine environment thereby increasing the availability of fish for recreational anglers (McGlennon and Branden, 1994; Lowry et al., 2014). The development and implementation of designed artificial reefs in NSW are considered a high priority by the recreational fishing community but the contribution of these reefs to recreational fisheries and local production is not well understood. Information describing the harvest composition and harvest by recreational anglers at these artificial reefs is needed to address these knowledge gaps and to provide a realistic evidence-based context for modeling studies. Simulation of realistic recreational harvest scenarios (e.g. using Ecopath with Ecosim (EwE); Christensen and Pauly, 1992; Pauly et al., 2000) may provide insights regarding the production potential of the system and hence the cost-benefit of additional designed artificial reef deployments.

Globally, researchers needing to estimate the harvest taken by recreational fishers from various artificial reef fisheries face a common problem. They must select and implement an appropriate sampling program to directly measure the harvest or use existing datasets to infer the harvest from the artificial reef fishery. There are many sampling options available but these vary greatly in their ability to deliver unbiased information about the fishery and their relative costs of implementation (Table 1; Pollock et al., 1994; Smallwood et al., 2011; Smallwood et al., 2012; Hartill and Edwards, 2015). All sampling options, including probability-based survey methods, can be subject to multiple forms of bias, which can be difficult to detect and quantify (Hartill and Edwards, 2015). The cheaper options (i.e. fisher logbooks, web-based data) provide information that has many known biases and are not representative of the fishery (Table 1; Pollock et al., 1994; Connelly and Brown, 1996; Bray and Schramm, 2001; Conron and Bridge, 2004; Smallwood et al., 2011; Smallwood et al., 2012; Hartill and Edwards, 2015).

Alternatively, the statistical rigor of a well-designed probability-based sample survey comes at a prohibitive cost because of the difficulty of selecting an unbiased sample of fishers that use the artificial reef fishery from the many thousands of private and public access points (i.e. on-site surveys) or from the massive urban population that reside in the Sydney area (i.e. off-site surveys—Table 1, Fig. 1). Hence it is necessary to consider the use of existing datasets to infer the harvest composition and harvest rates of recreational fishers using the artificial reef. Of course, the use of any existing datasets requires the adoption of various assumptions about the representativeness of the data used (e.g. potential bias that may arise from temporal variability between studies).

We present a case study from a nearshore designed artificial reef in Sydney, Australia that uses existing datasets from two different time periods to obtain: (a) a list of species taken by recreational fishers from the vicinity of the artificial reef; and (b) the harvest rates of those species. We estimate the recreational harvest of fish from the artificial reef fishery by number and weight. These harvest estimates are standardized per unit area to provide context for the relative size of the recreational harvest from an artificial reef fishery. We also use the standardized harvest data to make comparisons with other recreational fishery areas from which the fishable area is known.

2. Materials and methods

2.1. The artificial reef

The Sydney designed artificial reef (AR) is a large purpose-built individual artificial structure that was deployed in October 2011 for the purposes of enhancing recreational fishing. It is located approximately 1.2 km east of 'The Gap', at South Head, Sydney, New South Wales, Australia (33°50.797′S, 151°17.988′E, Fig. 1) in 38 m depth of water. The steel structure is 12 × 15 m and 12 m high with two 8 m tall pillars and is moored at each corner with chain and a 60 ton concrete block, resulting in a reef volume of 700 m^3 (Champion et al., 2015; Scott et al., 2015). The reef was designed with many open void spaces and towers that allow water flows through the structure. This water flow is important for supplying nutrient and plankton to the AR ecosystem and to promote the growth of sessile organisms and resident fishes (Connell and Anderson, 1999; Redman and Szedlmayer, 2009).

2.2. Data collection and analyses

Information describing the recreational fishery in the vicinity of the AR was obtained by: (a) direct observation of fishing trips using binoculars and from analyses of digital images that were used to quantify fishing effort at the reef (Keller et al., 2016) and (b) discussions with some recreational anglers that had visited the AR. The available information indicates that the fishery at the AR is mainly a drift and trolling fishery. This fishery mainly targets baitfish (e.g. yellowtail scad, *Trachurus novaezelandiae* and slimy mackerel, *Scomber australasicus*), inshore pelagic fish (e.g. yellowtail kingfish, *Seriola lalandi*) and demersal species (e.g. snapper, *Pagrus auratus*; blue morwong, *Nemadactylus douglasii* and flathead, *Platycephalus* spp.) that occur around the edges of the reef. Anglers are wary of anchoring near the reef because of the risk of fouling their fishing gear and anchor.