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S37-4　Are current harvests of seabirds sustainable?

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Abstract　This paper reviews seabird harvests towards evaluating whether monitoring, research and management are adequate to assess their sustainability. The low productivity of adult seabirds makes their populations extremely vulnerable to overharvest unless only eggs and chicks are taken. A critical lack of information on density dependence and other potential compensatory mortality adjustments makes assessment of sustainability very difficult even in the few cases where adequate monitoring and population research are underway. Research must be very long-term for robust demographic predictions. There is neither evidence for unsustainability of most current seabird harvests, nor evidence that harvesting is sustainable.

Key words　Seabirds, Harvesting, Sustainability, Conservation, Compensation, Regulation

1　Introduction

Seabird eggs, chicks and adults have been harvested for food in nearly all parts of the world in the recent past. Wing or tail feathers have been gathered for personal adornment, and down for bedding as well. Humans continue to consume eggs, flesh, proventricular oil and fats for sustenance, medicine and aphrodisiacs. There are also occasional uses of seabirds for fish bait and pet food, while large scale collection of guano for fertilizer potentially disrupts breeding success (Croxall et al., 1984; Nettleship et al., 1994). The high adult survival, low reproductive rate and delayed maturation of seabirds make them especially vulnerable to overharvest. Humans can easily exploit dense breeding colonies, which are often established on remote islands where monitoring or regulation of harvest is extremely difficult.

Reliance on agriculture and declines in hunter-gathering since the industrial revolution and associated urbanization have led to fewer harvesters and declining markets for seabird products. Protective legislation, harvest prohibition and land reservation became much more common around the world from the 1970s onwards. Poaching and the impossibility of enforcing harvest prohibitions (Croxall et al., 1984, Nettleship et al., 1994) make it clear, nevertheless, that these legislative restrictions and reservations are not sufficient safeguards to halt ongoing risk to seabirds. Much of the ongoing seabird harvesting is sporadic and unobserved.

The relatively development of population ecology and a growing awareness of the need for environmental sustainability globally are new reasons for hope that unsustainable seabird harvests will diminish. But is science applied well enough to guide most seabird harvests and can it adequately predict sustainability? What are the main complexities in seabird population dynamics that make the application of science difficult?

2　Assessing risk step one: measuring harvest intensity

Most current seabird harvesting goes unmeasured. The norm is typified by the situation described by Bergur Olsen (*in litt*., August 2002) from the Faroe Islands which has closed seasons on seabird harvesting but no bag limits and no intensive monitoring. Annual harvests of northern fulmar (*Fulmarus glacialis*) by Faroese are approximately 5 000–10 000 eggs, 50 000–100 000 juveniles caught from the water and 5 000–10 000 adults caught with a “fleyg” (net on a pole). About 5 000–10 000 guillemots or common murres (*Uria aalge*), 5 000–10 000 razorbills (*Alca torda*) and 1 000 Atlantic puffins (*Fratercula arctica*) are shot. 50 000–100 000 puffins are taken each year by fleyg. In addition, there is a take of 3 000 Manx shearwater (*Puffinus puffinus*) chicks, 500 northern gannet (*Morus bassanus*) chicks, 500 European shags (*Phalacrocorax aristotelis*), as well as 1 000–5 000 black-legged kittiwakes (*Rissa tridactyla*) taken from fishing boats and 500–1 000 young gulls (*Larus* spp.).

Estimation of the sustainability of these harvests is a huge undertaking for a relatively small scientific community. The large number of species involved and consequent differences in the spatial and seasonal distribution of the take makes it extremely difficult to assess harvest size. The very round figures and wide range of the “guesstimates” underscore their uncertainty. There are few reliable estimates of population size and productivity for most of the harvested species, so even a preliminary estimate of harvest intensity is not possible. The situation is paralleled in Greenland, Iceland, Canada and many other parts of the world where it is simply not practicable to apply science to assess risks.

Research into the traditional harvest of “titi” or sooty shearwaters (*Puffinus griseus*) chicks by Rakiura Maori in

New Zealand illustrates the more unusual end of the continuum, where a single species harvest is monitored with reasonable diligence. Initiation of research into the sustainability of titi harvests in 1994 is enormously encouraging and apparently unique (Taiepa et al., 1997). There are no other records in the literature of an indigenous people initiating and directing their own scientific research project to ensure that the birds remain plentiful enough for their grandchildren to harvest (Moller, 2001). The Rakiura project aims to determine what limits should be set on titi harvests and to develop monitoring tools that will enable the community itself to monitor long-term trends and changes.

3 Assessing sustainability by monitoring population trends

Monitoring trends in population abundance could provide a rough measure of harvest impacts, especially if trends in harvested and unharvested populations could be compared. However, there are several difficulties besetting such methods: (1) reliable measurement of a population trend can be extremely difficult, especially for burrow-nesting alcids and procellariiforms (Hamilton, 2000); (2) extraordinarily long data runs are needed to monitor trends reliably because of the long generation times in seabirds; (3) broad-scale changes in ocean ecology are occurring, so past population trends may not apply in future even if harvest pressure does not change; (4) differential migration between harvested and unharvested populations may remove evidence of harvest effects; and (5) unharvested colonies may be very different from those harvested in location and ecology in ways that affect population dynamics.

Population trends may be imperceptible or slight when viewed over short time spans, and trends in the first decade of a monitoring program may have been determined by the ecological events prevailing over the 20 years prior to it. Lag effects are likely if the age structure of the population has been affected by past events because seabird breeding and survival are age dependent.

In assessment of sustainability, the monitoring method on its own should only ever be used by researchers and environmental managers as a prioritization tool for choosing which species and populations to study intensively by a combination of other approaches. For example, declines in thick-billed murres (*Uria lomvia*), when coupled with knowledge that adults sustain heavy harvest pressure in Greenland and Canada (Falk and Durinck, 1992), signaled the need for urgent management of that particular harvest. A decline in sooty shearwaters coupled with large-scale harvesting is another potential case (Scofield and Christie, 2002).

4 Spatial comparisons of density for estimation of harvest impact

A quick test of large-scale harvest impacts could come from comparisons of the density of birds breeding in harvested and unharvested colonies. This approach, however, makes a critical assumption that density would have been the same in both colonies if harvest had not been imposed. Thus, in the case of breeding colonies of the sooty shearwater, unharvested Titi Islands tend to be smaller and have different vegetation than harvested ones, so any observed differences in density may not relate to harvest.

5 Demographic prediction approach

The "demographic prediction" approach assesses sustainability from calculations of inputs (reproduction and immigration) and outputs (mortality and emigration) and knowledge of the way density affects these parameters (density dependence). Demographic models can be built relatively quickly, so they can offer a first, best guess, of likely outcomes.

The main challenge in developing prediction models for seabirds such as the titi is the long time required to obtain good estimates of population parameters. Marine systems, and consequently the productivity and survival of seabirds, are extremely variable between years and decades, so accurate estimation of mean parameters is difficult. For example, Bradley et al. (1989) estimated the annual adult survival of short-tailed shearwaters (*Puffinus tenuirostris*) to be 0.912 ± 0.011. This may seem to be a very accurate estimate, and fitting reward for 40 years of research because the 95% confidence interval for annual survival is only 2.4%. However, if the confidence interval is expressed in terms of mortality, which is the rate at which adults fall out of the population, the confidence interval rises to 25%.

6 Compensatory, additive or exacerbated harvest effects: the key complexities for estimation of sustainability?

Even if demographic parameters can be measured accurately, the crucial assumption in constructing demographic models is whether harvest mortality is compensatory, additive or exacerbated. Re-laying after harvest is a simple example of compensation for smaller seabirds that can re-lay within the same breeding season, such as terns in the Seychelles (Feare, 1976).

Most potential compensatory mechanisms could operate through density dependence. If a pool of birds is prevented from breeding because of insufficient space, then harvest of eggs or chicks would have little effect on population numbers because "floaters" or "queuers" (mature birds waiting for space to breed) can reproduce earlier wherever harvest occurs. Reduction of populations of wandering albatrosses (*Diomedea exulans*) because of fishery bycatch has already led to earlier onset of reproduction (Tuck et al., 2001). Raising of young is energy sapping and time-consuming for seabirds and therefore risky (Weimerskirch, 2002). Harvesting of eggs or chicks could reduce the probability of the parents skipping breeding in the next season because curtailment of the current season relieves pressure on adults. It is also possible that adult survival will be enhanced if breeding is artificially disrupted. Density-dependent settlement rates may occur.

If metapopulation decline is triggered by harvesting, reduced density locally within a colony could release neighbors from interference competition and lead to increased egg and chick survival. Chick growth in less crowded colonies could improve fitness of fledglings and improve juvenile survival. Reduction in density may concentrate breeding in more high-quality areas of the colony so that per capita productivity or survival increases (Kokko et al., 2002).

Density dependence presents two related problems for demographers seeking to predict harvest effects. First, it is not known for most seabirds if the parameters measured on current populations are constrained by or released from density effects — it is usually impossible to know if the population under study is near carrying capacity or not. Secondly, measurement of the way parameters change over a range of densities is extremely difficult, especially when natural population change is slow or driven by fluctuation in environmental factors that alter carrying capacity itself. Researchers wanting to estimate density-dependent effects must measure vital rates when the population has been forced away from carrying capacity by some artificial perturbation, not simply when density varies in response to changing carrying capacity. The strongest inferences of density-dependent regulation effects in albatrosses come from putative fisheries bycatch impacts, but even here the perturbation is set against a background of generally warming seas since 1960 (Weimerskirch, 2002). This makes it difficult to partition effects of density *per se* from potential influences of changes in food or wind patterns that could affect foraging and chick provisioning.

The impacts of harvesting could in some circumstances exacerbate simple additive mortality. For example, disturbance of pre-breeders at nesting sites by harvesters can increase emigration. Selective harvesting of the larger chicks could increase impacts because such chicks are those most likely to be recruited (Hunter et al., 2000a). Many procellariids tend to switch mates if breeding fails, so harvesting could reduce mate fidelity. There may be delays in finding another mate and breeding is usually less successful when a new pair forms (Bradley et al., 1990), so overall productivity of the colony may be reduced by harvest. Humans walking on the breeding ground can collapse burrows and compact the substratum as well.

The traditional demographic approach to assessing risk is to calculate a "reproductive value" for estimating the relative impact of harvesting. According to calculations for such K-strategists as seabirds (slowly reproducing, long-lived species), removal of an egg or chick is likely to have much less impact on future population size than removing an adult. I suggest that an hierarchy of risk is driven partly by scope for compensatory effects and the parameter calculations embodied in reproductive value. If an egg is harvested, the chain of potential compensatory effects that could reduce harvest impact is long, such as re-laying, reduced disturbance, earlier onset of breeding. If a young breeding adult is harvested, there will be less opportunity for compensation, and so further exacerbation of harvest impact is possible.

Perturbation analyses are used to focus on the key parameters that effect population change. Apart from setting priorities for relative accuracy in measures of population parameters (Hunter et al., 2000b), elasticity and sensitivity analyses can guide researchers to the life stages most important for determining whether compensatory or additive mortality effects result from harvesting.

7 The need for corroboration from several different approaches

The above complexities potentially reduce the reliability of the demographic prediction method for assessment of sustainability. Demographic modeling, however, is not constrained by the fundamental weakness of monitoring and density comparison approaches that cannot predict what will happen if ecological conditions or harvesting changes in future. Monitoring and spatial comparisons look backward, demographic modeling looks forwards. The most reliable predictions will use a combination of the three approaches. Monitoring can be used to test the accuracy of the demographic prediction approach by providing an "external check" on predicted trends. Managers should be sceptical of any model that predicts a rate of population change different from that observed by monitoring, or if predicted densities between harvested and unharvested colonies are different from those actually observed.

8 General discussion: are current harvests sustainable and can science help?

It has taken eight years of hard work by an annual team of two to three scientists and three students assisted by six field volunteers to establish the Rakiura titi harvesting research project. First predictions of sustainability are expected in 2006, 13 years after starting research. Many communities would not have the time, resources or scientific capacity to mount such a project to assess the sustainability of their local seabird harvests, even of just one species.

The complications associated with compensatory, additive or exacerbated harvest effects will make even preliminary predictions of harvest sustainability very approximate. And should researchers be able to model current dynamics satisfactorily, long-term prognosis for harvest sustainability may yet be determined by global environmental changes that are even harder to predict. For example, there is correlative evidence that more frequent and intense El Niño climate fluctuations depress adult titi survival, the key determinant of population trajectory with or without harvest (Lyver et al., 1999). Anthroprogenic climate change may be increasing the intensity and frequency of El Niños and become the key determinant of sustainability. Our team of population ecologists has therefore had to shift the emphasis of research to climatology and oceanographic systems, subjects well beyond their own expertise. The complexity of oceanic and climate systems and the multitude of threats encountered by far-ranging seabirds demands a multi-disciplinary approach for guiding seabird conservation.

The expense, duration and complexity of the necessary research entail strict prioritization, and it is the harvests themselves that deserve most scrutiny. Declining populations merit immediate attention, particularly where life stages with the greatest reproductive value are taken, in the order of young adults > old adults > pre-breeders > juveniles > fledglings > chicks > eggs.

More scientific research into harvests, and incorporation of the traditional environmental knowledge of the harvesters, can help guide management and reduce environmental and cultural risks. In nearly all ongoing seabird harvests, there is neither evidence for unsustainability, nor evidence that harvesting is sustainable. Premature conclusions that harvests are sustainable, or that they are causing declines, must be avoided. Attempts to impose harvest restrictions from outside the harvesting community on false or unproven claims of unsustainability are likely to fail and alienate the key people involved: the seabird harvesters themselves.

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