

# Seamounts: Ecology, Fisheries & Conservation

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## Chapter 2

# How many seamounts are there and where are they located?

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### Abstract

Knowledge of seamount distributions is becoming more important in a wide range of research fields. Originally dominated by geophysical research, the identification of seamounts and their distribution now ranges from determining tectonic plate evolution to habitat mapping of seamount species. This, coupled with growing interest from commercial and geopolitical bodies, has further increased the need to geo-locate seamounts and determine the extent of their abundance. Whatever the method used, generally a seafloor peak is identified. Characteristics of the seafloor topography surrounding the peak are then used to determine whether the peak is the top of a seamount. The technologies used to identify seamounts from seafloor topography have advanced in sensitivity and coverage. This has resulted in a variety of methods to identify seamounts and estimate their abundances. The different features of two key techniques for seamount detection, sonar and satellite altimetry, have resulted in two research approaches. Due to coverage limitations, sonar seamount abundance estimates must be based on seamount sub-samples and extrapolated for larger coverage. Satellite altimetry is capable of near-global coverage, but is only able to identify and geo-locate large seamounts (higher than 1 km); it must therefore extrapolate abundance for smaller seamounts. In an attempt to create a global geo-dataset of seamounts, we have developed a relatively simple methodology for identifying and geo-locating potential seamounts. Using bathymetry data derived from altimetry, approximately 14000 large seamounts greater than 1 km in height were identified. The resulting geo-dataset of seamounts offers an indication of the distribution of seamounts over the seafloor and shows that over 60% of seamounts occur in the Pacific Ocean. It was also determined that 50% of the seamounts occur within the exclusive economic zones (EEZs) of countries. Detailed datasets of seamount locations will help to identify potentially vulnerable regions and improve the understanding of ecological processes involved. This will in turn be an important contribution to the management and conservation of seamounts.

### Introduction

The statement ‘the surfaces of Mars, Venus, and the Moon are much better mapped than Earth’s ocean floors’ (Sandwell *et al.*, 2002) becomes clearly evident when one attempts to

determine seamount abundance and seafloor distribution. To date, global bathymetric maps largely rely on interpolation to create a complete seafloor topography. In fact, the quality of depth values for some large areas of current global bathymetric data has been likened to the extrapolation of the US topography from its interstate highways (Sandwell *et al.*, 2002). That said, many attempts, mostly geophysical, have been made to determine the extent of seamount seafloor coverage since the mid-twentieth century. The importance of locating and describing seamounts is now reflected in research ranging from the explanation of oceanic crust evolution to habitat mapping of species associated with seamounts, with a growing engagement of commercial and geopolitical interests (see Chapters 1 and 20).

Just as the interest in seamount distributions has increased, so have the forms of data acquisition and analysis broadened over time. Originally relatively limited tracks of bathymetric profiles were used to estimate seamount numbers for single or partial ocean basins. With the accumulation of bathymetric data and advances in a number of bathymetry acquisition techniques, it is now possible to extrapolate seamount populations at a global level.

### ***Bathymetry acquisition and data***

The development of active sonar in the early 1900s provided the first means of research into seamount dimensions and their seafloor distribution. At its most basic, active sonar measures depth by timing the return of a sound pulse reflected by the seafloor. A towed or hull-mounted sonar device would measure the bathymetric profile along the path of a research vessel. The early active sonars, wide and single narrow beam, only produced single-dimensional profiles of the seafloor. Wide-beam sonars had little resolution of the actual direction of the sound pulse, so only indicated the shallowest depths within the swath of the sonar track. Single-narrow-beam sonars improved the accuracy of depth measurements by having the ability to focus a sound pulse. Their shortcoming was the limited coverage of the seafloor by a single pulse. The introduction of multi-beam sonar filled the need for accurate depth measurements across a wide track. This system combines the advantages of the narrow- and the wide-beam systems to yield accurate depth profiles across a wide swath. Essentially, in a single pulse, multiple narrow beams simultaneously return more than 100 soundings that measure depth across a wide swath perpendicular to the ship. This allows two- and three-dimensional mapping of the seafloor topography at a high resolution.

Although multi-beam bathymetric readings are still the preferred method for high-resolution bathymetric mapping, their use in global analyses of the seafloor is limited, since only a ship's track is mapped. Trying to obtain a global bathymetric dataset in this fashion would be prohibitively expensive and impractical. Satellite altimetry, a more recent technology, has been used to meet the need for global bathymetric coverage. Satellite altimetry measures the difference between the sea surface and Earth's ellipsoid, which is then used to calculate the Earth's geoid (see Box 1.1).

Many early altimetric seamount studies used US Navy *Seasat* satellite data (e.g., Lararewicz and Schwank, 1982; Dixon *et al.*, 1983; Baudry *et al.*, 1987; Craig and Sandwell, 1988). However, the *Seasat* coverage was sparse, with tracks separated by around 100 km. With such large spacing, any seamounts between tracks would have been

missed or incompletely described (Wessel, 2001), affecting any global estimates (e.g., Craig and Sandwell, 1988). More recently, the combined datasets from the US Navy *Geosat* and European Space Agency *ERS-1* satellites have provided a much denser altimetric dataset with only a few kilometres between tracks. Although the resulting gridded map only ranges from 72° north and south, this data has provided the basis for many of the most current global seamount distribution studies (e.g., Wessel, 2001).

While a global bathymetric grid can be inferred from altimetry and sonar bathymetry tracks, such grids are difficult to produce and vary widely in quality and resolution. It is important to remember this when examining any methods that attempt to extract topographic features from these gridded datasets.

There are a number of global bathymetry grids available, mostly composed of various baseline sources, including bathymetric map contours (GEBCO, 2003), echo-sounding tracks, and satellite altimetry. Arguably one of the most frequently used global bathymetry grids is that based on a model pioneered by Dixon *et al.* (1983) from which Smith and Sandwell (1997) interpolated an almost global seafloor bathymetric dataset. They combined *Geosat/ERS-1* altimetry data and bathymetric soundings to produce a bathymetric grid at a resolution of approximately 2 arc minutes. The Smith and Sandwell (1997) dataset has also become the basis for other bathymetry grids that incorporate localised non-altimetric sources (e.g., ETOPO2, 2001; NRL DBDB2, 2003; GINA, 2004) to attempt a complete global coverage. Efforts to combine bathymetric datasets can lead to resolution degradation and in some cases, mistaken registration or mismatches between mapped features and their real-world position (Marks and Smith, 2006). Seafloor topography datasets for global analyses are expected to become increasingly useful with access to higher-resolution satellite altimetry and as military sonar archives are declassified.

### ***Seamount identification***

The ability to characterise seamounts from bathymetric data is key to any attempt to estimate seamount abundance. Seamounts are identified using a number of techniques, all of which involve a topographic feature to fit the criteria of a predefined seamount shape. Menard (1959) first suggested a comparative seamount definition and estimated seamount numbers for the Pacific basin. His definition of a seamount as ‘an isolated elevation from the seafloor with a circular or elliptical plan, at least 1 km of relief, comparatively steep slopes and a relatively small summit area’ (Menard, 1964) has provided a basis for many definition variants throughout the literature. The definition of a seamount in this book (see Preface) is evidence of the way in which different scientific disciplines identify the term ‘seamount’.

Despite advances in identification methods, the basic process of isolating seamounts from baseline data has remained the same. This generally involves first identifying topographic maxima or peaks and then comparing the individual surrounding topographic dimensions of each peak with a set of parameter thresholds. Since two-dimensional bathymetric charts or sonar tracks of the seafloor have become available, many studies have relied on closed contours to single out peaked features (e.g., Batiza, 1982; Fornari *et al.*, 1987; Abers *et al.*, 1988; Jaroslow *et al.*, 2000). The introduction of gridded data has introduced automated methods that compare neighbouring grid values to determine local maxima (e.g., Wessel and Lyons, 1997; Wessel, 2001).

With the steady increase in quality and types of data used to identify seamounts, various seamount characteristics have been qualified and incorporated into models. The circular or elliptical nature of a seamount's base perimeter, either visually identified or measured by a length/width ratio, has proved to be a robust parameter and has been used persistently (e.g., Batiza, 1982; Epp and Smoot, 1989; Smith and Cann, 1990; Jaroslow *et al.*, 2000). Batiza (1982) also introduced a seamount slope threshold of  $>6$ , broadened to  $17^\circ$  by Smith and Jordan (1988). Height-to-radius ratio has been found to be fairly constant across seamount sizes (Simkin, 1972; Lacey *et al.*, 1981; Jordan *et al.*, 1983), although Abers *et al.* (1988) noted that larger seamounts are more regular in shape than smaller ones. Analysis of wide-beam sonar profiles by Jordan *et al.* (1983) used a seamount flatness threshold, defined by the ratio of the radius at the top to the radius at the bottom, to provide a definition of a seamount as approximating a truncated right circular cone.

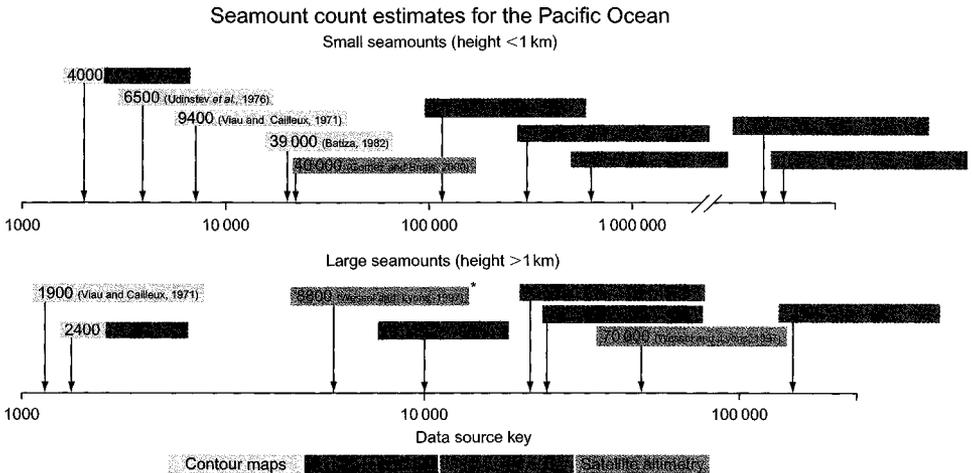
Craig and Sandwell (1988) pioneered the use of the *Seasat* satellite altimetry data in seamount distribution research. Possible seamounts were located by visually identifying a characteristic peak and trough on the along-track slope of the geoid or vertical deflection profile (Craig and Sandwell, 1988). By measuring the dimensions of these signatures, researchers could estimate the diameter of a seamount using a modelled Gaussian seamount shape. Wessel and Lyons (1997) used the vertical gravity gradient (VGG) or geoid curvature derived from the denser *Geosat/ERS-1* altimetric data to identify seamounts. Their process involved the automated detection of local peaks in the VGG and the use of a closed VGG contour threshold to isolate possible seamounts. The potential seamount locations were then modelled using a Gaussian seamount shape to estimate seamount radius and height. Their model also incorporated the ability to determine dimensions of overlapping seamounts where more than one maximum occurred within a closed contour. Separating seamounts from peaks along fracture zones and ridges is a persistent problem in the automated identification of local peaks (Craig and Sandwell, 1988; Wessel and Lyons, 1997). Wessel and Lyons (1997) managed to reduce this problem by excluding seamounts within a certain distance of a fracture zone or trough.

The size of seamounts to include is a factor of constant concern within seamount location and abundance research. Height or relief is the most common parameter used to define the size of a seamount. Although originally defined as greater than 1 km (Menard, 1964), seamounts are now characterised at a range of heights from greater than 500 m (Cailleux, 1975) to greater than 50 m (Smith and Cann, 1990). The bathymetric data acquisition technique has furthered the importance of height as a limiting parameter. Modern sonars are able to detect features rising only metres from the seafloor, while altimetry is still restricted to identifying seamounts greater than 1–2 km. This has led to a distinction between large and small seamounts often used when extrapolating seamount abundances.

## Seamount count methodologies

The estimation of seamount numbers over the years has been a complicated and difficult task. Most efforts have been restricted to single or partial ocean basins due to limited coverage by shipboard sonar tracks. The incomplete nature of bathymetric data, either through coverage or resolution, has led to the development of statistical techniques

to extrapolate seamount abundances. Areal statistics were pioneered by Menard (1959), who treated bathymetric profiles as random samples that yielded an areal/density value of a random distribution of seamounts. Seamount numbers from areal distribution studies have varied widely over time, often using different height ranges, making it difficult to contrast investigations in a standardised manner (Smith, 1991). For the Pacific Ocean, Menard (1959) initially estimated 10 000 large seamounts (>1 km in height). Since then, estimated numbers have ranged widely with small seamounts potentially numbered in millions (see Fig. 2.1).



**Fig. 2.1** Seamount abundance estimates for the Pacific Ocean from key published literature. The symbol \* indicates a count of seamounts directly identified from underlying data, otherwise they will have been statistically derived. Depicted seamount estimates are rounded.

Early on it was noticed that the numbers of Atlantic seamounts decreased as the function of height increased (Litvin and Rudenko, 1971; Udinstev *et al.*, 1976). Batiza (1982) concluded that small seamounts were more abundant than larger ones and suggested that the size–frequency distribution of Pacific seamounts followed a Poisson-like trend. Although the Poisson distribution assumption has been carried throughout subsequent studies, its validity has been debated. Jordan *et al.* (1983) suggested that seamounts tended to form clusters or were strung out in chains (see Chapters 1 and 4).

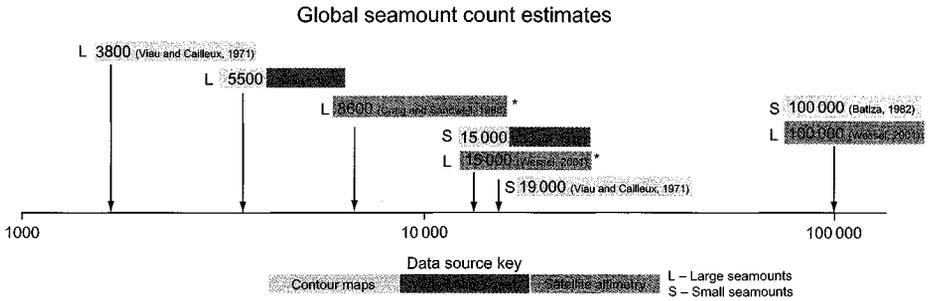
Jordan *et al.* (1983) used wide-beam sonar profiles to compare the suitability of exponential and power-law models in explaining the size–frequency distribution of seamounts. They found that an exponential size distribution fitted reasonably well for a range of larger seamounts in the Eastern Pacific. Most subsequent studies of seamount size–frequency distributions, using wide- and multi-beam sonar, have focused on those seamounts less than 3 km in height (Smith, 1991) and have used the exponential model. It was noted that for smaller seamounts, within the range of 100–1000 m, the exponential model was only a marginally better fit than the power-law model (Abers *et al.*, 1988).

The introduction of altimetry data provided the first opportunity to estimate seamount numbers at a near-global level and describe the population of larger seamounts adequately

(Smith, 1991). Craig and Sandwell (1988) conducted the first comprehensive examination of global seamount distribution using satellite altimetry. Of the 8556 seamounts they located, one-quarter were previously uncharted (Craig and Sandwell, 1988). This was despite having to use an incomplete dataset due to the early failure of the *Seasat* mission.

Using altimetric data derived from VGG, Wessel and Lyons (1997) investigated the Pacific Ocean seamount population. They then examined the fit of their detected Pacific seamounts (8882) to the exponential and power-law models and concluded that the fit to the model was adequate for seamounts >2 km in height (Fig. 1.8).

Wessel (2001) expanded the examination of the VGG data to a global level and identified 14 639 large seamounts with an extrapolated global population of approximately 100 000 seamounts over 1 km (Fig. 2.2). More than half of the seamounts identified by Wessel (2001) occurred on the Pacific tectonic plate, with numerous seamounts occurring on the African plate (Eastern Atlantic and Western Indian Oceans), Indo-Australian plate (North and Eastern Indian Ocean), and Nazca plate (Central Eastern Pacific Ocean).



**Fig. 2.2** Global seamount abundance estimates for both large and small seamounts from key published literature. The symbol \* indicates the number of seamounts directly identified from underlying data, otherwise they will have been statistically derived. Large seamounts are those >1 km in height, while small seamounts are below <1 km. Depicted seamount estimates are rounded.

Despite improved technology and statistical techniques to isolate individual seamount features, there is still a clear difference in the capacity of the various techniques to acquire bathymetry, which leads to varying estimates of seamount numbers. Although bathymetric data derived from altimetry provide a near-global coverage and an opportunity for validation of seamount numbers, currently available data lack resolution to detect seamounts <2 km high (Wessel and Lyons, 1997). Wessel and Lyons (1997) suggested that only a third of the seamounts in the Pacific greater than 1 km in height were visible in current satellite data and that only a third of those were characterised in their study. On the other hand, while the latest sonar technology is able to detect seamounts down to less than 100 m in height, this technology is still restricted in seafloor coverage and must infer numbers through areal density calculations.

### *Spatial location of seamounts*

Seamounts are becoming more important to the scientific community as shown by the breadth of contributions to this book. Good geo-referenced seamount datasets are urgently

needed for research and to inform fisheries conservation and management agencies. In an attempt to produce such a dataset, the Sea Around Us Project (SAUP; [www.seaaroundus.org](http://www.seaaroundus.org)) at the University of British Columbia uses a generalised definition to fit seamounts into ecological and management contexts. Unlike more comprehensive global studies by Craig and Sandwell (1988) and Wessel (2001), which use stricter seamount definition criteria in a geophysical context, the SAUP is primarily concerned with the location of seamount-like features regardless of their tectonic characteristics. The SAUP criteria assume that a possible seamount has a rise of 1000m or more from the seabed and is roughly circular or elliptical in shape. Parameter thresholds used attempt to reflect this most basic of definitions for large seamounts.

The ETOPO2 global elevation dataset is used by SAUP as baseline bathymetric data. ETOPO2 contains the Earth's topographical elevations in a grid format and was created by the US National Oceanic and Atmospheric Administration (NOAA). For the ocean floor, it incorporates a number of bathymetric datasets, though it mainly consists of the Smith and Sandwell (1997) altimetry and sonar track derived bathymetry. The dataset is supplied at a 2 arc minutes grid cell resolution ( $\sim 13.7 \text{ km}^2$  at the equator), thus allowing a reasonable scale at which to perform a generalised global analysis for large seamount-like features.

The initial process consisted of determining the locations of all detectable peaks identified as local maxima in the elevation data. This was performed with the use of the ESRI (1999–2002) ArcGIS software's flow direction and sink algorithms. The ETOPO2 data were used in an ESRI grid format for the grid cell by grid cell analysis. The elevation data were prepared by first eliminating all land grid cells (any elevation above 0) and then converting negative elevation values to positive numbers. This allowed the following ESRI hydrology algorithms, designed to detect downhill flow direction and sinks, to identify the uphill flow directions and peaks.

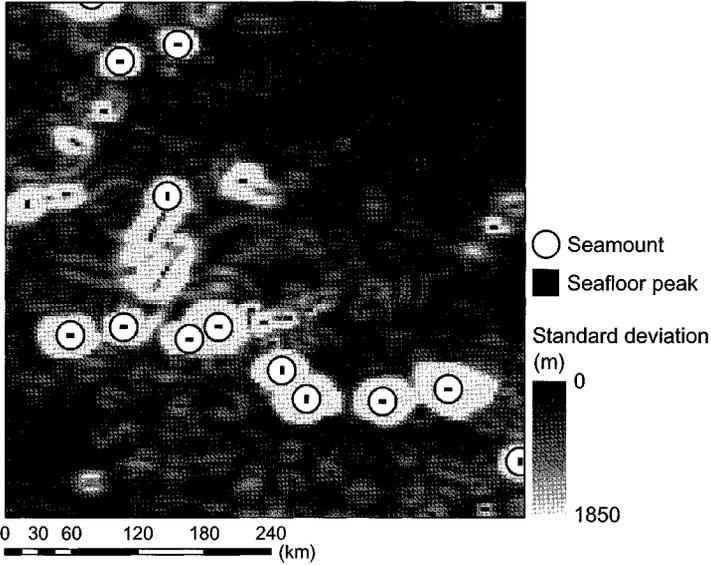
The ESRI flow direction algorithm was first used on the bathymetry data. This algorithm produces a grid in which each cell is allocated a flow direction value determined by the steepest descent from the immediate surrounding grid cells. Undefined flow directions occur when no flow direction can be determined for a grid cell. The conditions that cause this are when all surrounding grid cells flow into a single grid cell or when two adjacent grid cells flow into each other. The ESRI sink algorithm is used on the resulting flow direction grid to identify all grid cells that have undefined flow directions. The resulting sink, or its inverse, the seafloor peak grid, can then be overlaid with the ETOPO2 depth grid to indicate all identifiable seafloor peaks.

Once the peaks are detected, two methods are used to identify possible seamounts. The first involves isolating the peaks that have a significant rise from the ocean floor. The second isolates peaks with a circular or an elliptical base in an effort to eliminate small peaks found along steep ridges. The overlapping seamounts found using both these methodologies are used as the SAUP seamount dataset. To determine the overlap, the points of the two datasets have to be within 2 arc minutes of each other.

### ***Method 1***

The initial part of the process involved producing a grid of standard deviations of depth to accentuate any depth changes across the ocean floor. The neighbourhood statistics

function in ESRI's ArcGIS Spatial Analyst software was used to produce a grid with a depth standard deviation value for each ETOPO2 depth grid cell as compared to its immediate neighbourhood. To enable the identification of possible seamounts, the standard deviation and the seafloor peak grids were overlaid. Using ESRI's ArcGIS Spatial Analyst, each peak grid cell was then compared to a  $5 \times 5$  kernel (localised grid) of its neighbourhood on the standard deviation grid. If any grid cells within the kernel were above a 300-m standard deviation, the focal peak grid cell was considered a possible seamount (see Fig. 2.3).

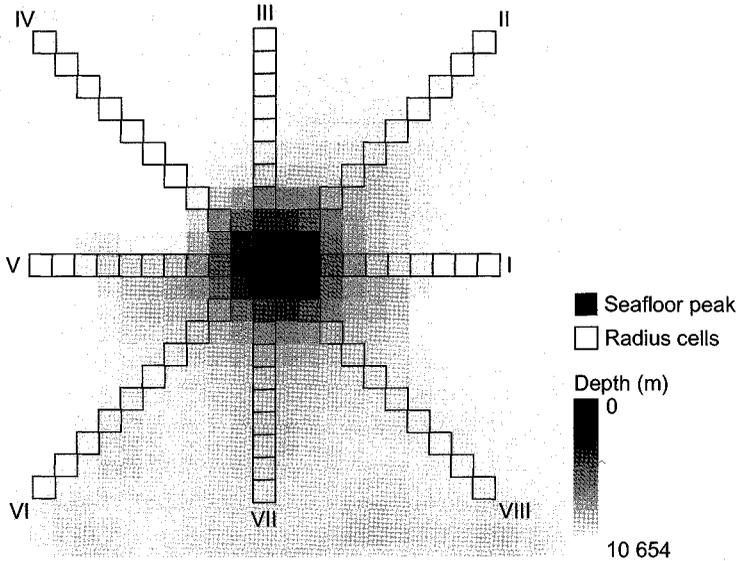


**Fig. 2.3** An example of the results of Method 1 for seamount identification. Potential seamount-like features are identified from the standard deviation of depth values surrounding detected seafloor peaks. The peaks marked as seamounts have passed surrounding depth standard deviation threshold criteria.

### *Method 2*

The second method compared the raw peak grid dataset directly with the ETOPO2 data. An algorithm was developed that scanned ETOPO2 depths approximately 90 km around each peak along 8 radii of at  $45^\circ$  intervals (see Fig. 2.4). The lowest and the highest depths over the radii (10 grid cells per radius near the equator, more at higher latitudes) were then recorded. A raw peak was considered to be a seamount when the following three conditions were met:

1. Each of and all the 8 radii included depths differing by at least 300 m. This helped eliminate all peaks of insignificant mounds.
2. If 2 radii included depths between 300 and 1000 m with the shallowest point being closer to the peak than to the deepest point, and if the radii formed an angle of less than  $135^\circ$ . This condition was created to help separate ridges from seamounts.
3. At least 5 of the 8 radii around a peak included depths with a difference of at least 1000 m, with the shallowest point being closer to the peak than to the deepest point.



**Fig. 2.4** Seamount identification Method 2 uses 8 grid cell radii relative to each seafloor peak. These radii are then used to test seafloor depth criteria to determine whether a peak is a potential seamount.

## Numbers of large seamounts

The two methods produced different numbers of potential seamounts, with the first method producing almost double the amount of the second method 30314 against 15962. The overlapping points resulting from the two methodologies identified 14287 possible seamounts. The range of seamount numbers also varied separately for the two methods and their set thresholds. Smaller potential seamounts were identified by Method 1 when the standard deviation threshold was lowered, thus increasing the seamount count (see Table 2.1). Method 2 remained relatively constant, with estimates between 15000 and 20000 seamounts, depending on the depth change threshold set between 100 and 500m. As the threshold was increased for Method 2, the non-linear variation in seamount counts could be attributed to the fact we took into account the proximity to the nearest seafloor rise and the depth of the valley between peaks as well as the change in surrounding depth (see Table 2.1).

**Table 2.1** Seamount prediction counts for the two separate methods using various thresholds. Method 1 in the SAUP seamount identification methodology uses standard deviation of depth values surrounding detected seafloor peaks, while Method 2 uses raw depth values surrounding detected seafloor peaks.

Local depth standard deviation or depth threshold (m)	Potential seamount count	
	Method 1	Method 2
100	~142 000	~20 000
300	30 314	15 962
500	~8 500	~18 000

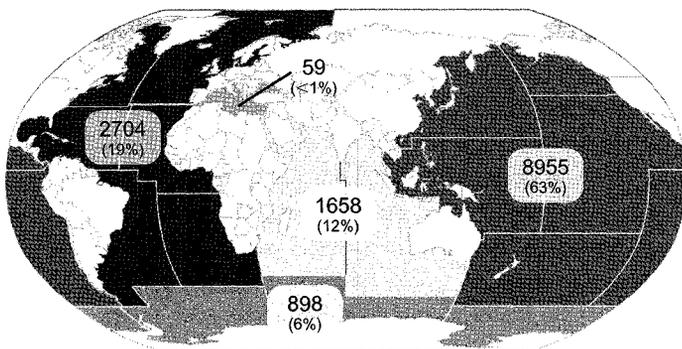
The SAUP study has found a relatively simple way of inferring potential seamounts from mid-resolution bathymetric data. Although there is no reference to volcanism in the model parameters, a point dataset of seamount-like features was achieved. However, the production of these potential seamount locations should only be used as a guide for global seamount distribution and is by no means a definitive dataset. Several points that should be noted when making any conclusions with the dataset are as follows:

1. Criteria for the seamount inferences were only sensitive to a broad level, with the definition of seamounts still very generalised. This sensitivity is directly influenced by the depth and depth standard deviation thresholds. The sensitivity of the thresholds is also directly influenced by the resolution of the underlying bathymetry data. Any features smaller than the cell size of the bathymetry data will have had their dimensions blurred with surrounding features, which could bring them outside of the inference criteria bounds. All predicted seamount locations are only indicative of very large seamounts, since the resolution of the underlying bathymetric and altimetric data will only allow for the confident identification of features  $>2$  km high (Wessel and Lyons, 1997).
2. As expected, many of the predicted seamounts occurred along mid-ocean ridges, although Method 2 incorporated criteria that attempted to eliminate peaks along ridges and fracture zones. On the flip side, our attempt to eliminate peaks along ridges could also eliminate actual seamounts. It was decided to keep the results conservative by maintaining relatively restrictive criteria for Method 2 to reduce error.
3. The area around each peak, tested for seamount characteristics, is restrictive in nature and would affect the results to some degree. The kernel used by Method 1 equates to an area of approximately  $342 \text{ km}^2$  at the equator. It was hoped that a kernel of this size would allow the detection of large seamounts while eliminating large peaked banks. This kernel size could be further examined to optimise the sensitivity of the analysis. Likewise the lengths of radii in Method 2 could also be optimised. While aiming to be wide enough for the largest of seamounts, the radii could also include some features classed as semi-circular banks or guyots.
4. All points were included, regardless of their proximity to a coastline. As a guide, it was found that around 5% of the predicted seamount locations occurred within 20 km of a coastline. Due to resolution constraints, there is the possibility that the ETOPO2 bathymetry may have registered some small land structures as below sea level, resulting in their inclusion in the dataset.
5. The predicted seamount locations generated by the SAUP model have a much lower resolution than the underlying bathymetric data. One of the results of the ESRI flow direction and sink algorithms is paired points, where two cells flow into each other indicating a sink interpreted in this analysis as a peak. The two methods used were conducted with these paired points present, but the final locations had any paired peaks reduced to a single location at a mid-point between the two, maintaining the shallowest depth value of the pair. The error in real-world location is also enhanced by the mistaken registrations in the underlying ETOPO2 bathymetry dataset (Marks and Smith, 2006).

Ground truthing was performed on a dataset of known seamounts produced from a combination of data recorded in the US Department of Defense (1989) and SeamountsOnline (Stocks, 2003). It was found that approximately 60% of the known seamounts were within 30 arc minutes of predicted seamounts. The 30 arc minutes resolution is used by the SAUP's ecosystem and fisheries models. The total number of large seamount features identified was also notably similar to the number identified by Wessel (2001), although it is evident that the locations of many seamounts differed due to the differences in criteria and the context of the research. As expected, the inferred SAUP seamount count was well below Wessel's extrapolated estimate of 100 000, but it did far exceed numbers identified or estimated (Fig. 2.2) in some previous studies (e.g., Viau and Cailleux, 1971; Cailleux, 1975; Craig and Sandwell, 1988). However, as mentioned above, the dataset used by Craig and Sandwell was incomplete.

### Locations of large seamounts

Since many studies are restricted to a particular ocean, an attempt to get an estimate of predicted large seamounts per ocean was performed. The statistical areas of the United Nations' Food and Agriculture Organization (FAO; [www.fao.org](http://www.fao.org)) were used to identify oceans (see Fig. 2.5). Although these areas do not exactly fit the oceanic boundaries in other studies, a broad comparison was possible. Despite previously noted locational differences of potential seamounts, the number of seamount features for the Pacific Ocean falls within the bounds of the 8882 seamounts identified by Wessel and Lyon (1997). As expected, the modelled numbers fall well below the size–frequency estimates of around 30 000 by Smith and Jordan (1988) and Wessel and Lyon's (1997) own extrapolation of around 70 000 possible seamounts (see Fig. 2.1). The Atlantic contained roughly a fifth of the identified seamount features, while the Indian Ocean held just over a tenth. The counts for the Southern Ocean would have been underestimated by the FAO areas, as the ocean actually reaches the southern coast of Australia. A detailed list of seamount numbers by FAO statistical areas is presented in Table 2.2.



**Fig. 2.5** Potential large seamount counts identified by this methodology for oceans defined by the statistical areas of the United Nations' Food and Agriculture Organization.

**Table 2.2** Potential seamount counts for oceans defined by FAO statistical areas and those within EEZs.

Ocean areas	FAO area	Potential large seamounts	Potential large seamounts within EEZs
<i>Pacific</i>	All	8955	5415
Eastern Central	77	2735	1768
Northeast	67	265	89
Northwest	61	1350	720
Southeast	87	939	239
Southwest	81	996	353
Western Central	71	2670	2246
<i>Atlantic</i>	All	2704	745
Eastern Central	34	536	103
Northeast	27	325	114
Northwest	21	83	6
Southeast	47	639	127
Southwest	41	452	151
Western Central	31	669	244
<i>Indian</i>	All	1658	576
Eastern	57	588	162
Western	51	1070	414
<i>Mediterranean and Black Sea</i>	37	59	0
<i>Southern Ocean</i>	All	898	185
Atlantic, Antarctic	48	498	127
Indian Ocean, Antarctic	58	212	58
Pacific, Antarctic	88	188	0
<i>Arctic</i>	18	13	0
<i>Total</i>		14 287	6921

EEZ data were licensed from Global Maritime Boundaries Database (2003), General Dynamics Advanced Information Systems (<http://www.gd-ais.com/Capabilities/offerings/sr/gmbd.htm>).

The occurrence of the SAUP-inferred seamounts within EEZs was tested to indicate the proportion of large seamount that could be individually managed or incorporated into an existing management programme under a country's jurisdiction. It was determined that approximately 50% of potential seamounts occurred within EEZs worldwide (see Table 2.2 and Fig. 2.6). With many possible large seamounts occurring in the high seas, the first attempt of ecosystem management in an international situation may be necessary (Alder and Wood, 2004). Of the seamount features found within country maritime jurisdictions, approximately 60% of the Pacific large seamounts occurred within an EEZ. The highest numbers were in the EEZs under the administration of industrialised countries such as the USA, France, Japan, and New Zealand. Approximately 28% and 35% of seamount features in the Atlantic and Indian oceans, respectively, were within EEZs.

The SAUP methodology has provided a simple way of generating a global seamount dataset directly from elevation data. Although the current output is suitable for a generalised global analysis, it is aimed at providing a possible approach that can be improved and refined with further research and higher-resolution bathymetric datasets.

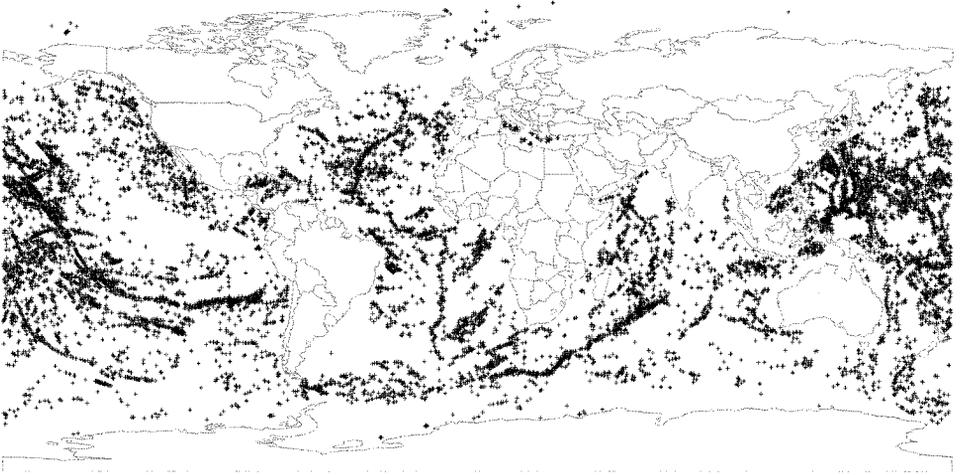


Fig. 2.6 Potential large seamount points inferred by the Sea Around Us Project analysis.

## Importance of mapping seamounts

The availability of detailed datasets of global seamount locations is a major requisite for understanding ecological processes, identifying potentially exploited areas, and effective management proposals. For example, the biogeography and biodiversity of seamounts (Chapter 13) will never be fully understood until detailed maps of seamount locations are available. On the other hand, quantifying seamount fisheries catches (Chapter 18) will only be possible after obtaining a detailed global distribution of seamounts.

As mentioned above, many seamounts occur within the EEZ of maritime countries, with approximately half occurring in international waters. The general perception that most seamounts occur outside of the areas under national jurisdiction is thus incorrect. This has profound implications for the ways in which appropriate levels of seamount management protection are achieved. Beyond areas under national jurisdiction, the responsibility to preserve seamounts as part of the global common heritage belongs to all nations (Alder and Wood, 2004). Clearly, this represents a challenge for the international community and individual countries wishing to conserve the biodiversity of these ecosystems (Chapter 20).

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