An Assessment of Turtle Population Analysis Data Needs

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Population size estimates are only one of a number of statistics required to fully understand the dynamic properties of a population. In addition rates of numerical change are usually estimated from birth and death rates. However, the usefulness of a set of parameters chosen to analyze a population depends upon their relative ease of estimation, the extent to which they collectively describe the significant properties of a population, ability to extrapolate beyond the data from which they were calculated, the directness of their relationship to population processes and their generality. A choice of parameters is usually the result of a compromise between these criteria. The main parameters for which estimates are usually derived are listed in the outline which is included as an Appendix of this report.

The most conspicuous species in Southeast U.S. waters is the loggerhead, Caretta caretta. This report specifically adresses the data now available for this species and the green turtle, Chelonia mydas. The necessary data required for complete analysis is defined and hopefully this report will offer some direction of efforts which will result in parameter estimates for all marine turtle species.

While the immediate task is to derive realistic estimates for population sizes by area at the present time (i.e. point in time and space estimate), the ultimate goal is population analysis. The cause-effect relationship between all the above parameters often requires concurrent estimation and evaluation.

In this report I will evaluate the status of turtle population analysis in relation to the available data and present data collecting techniques. The outline on population analysis which follows summarizes the information usually desired and/or required for complete population analysis. Each parameter will be discussed in this report. However, because of the interrelationship between parameters, there is necessary redundancy.

I. Population Definition

Limits

The analysis of a population implies that the population under consideration is defined and bounded. Hence, the first problem is encountered.

Because dispersal patterns and migration routes are unknown for all stages, a marine turtle population is usually temporally bounded within the nesting season and spatially limited to state, beach, island, etc. (whichever is most convenient). Thus, "populations" are considered composed only of female recruits and remigrants. Assuming "enough" males are present, this restriction is no barrier to population analysis. Until there is evidence that refutes a 1:1 sex ratio, the number of adult females will have to be assumed to represent half of the total breeding population.

The breeding season is known for all species in our area from tag-recapture data. Marine turtles demonstrate a birth-pulse type of reproduction and hence nesting in the Southeast U.S. area is not continuous but restricted, in general, to late spring and summer.

It appears likely that sub-adult and adult loggerheads feed as far north as New York waters, and move seasonally in a north/south direction. Hence, for a "population" which is defined to include sub-adults and non-breeding adults, only density estimates may be obtained from pelagic aerial surveys. Seasonal movements may also be determined from pelagic aerial surveys and result in density estimates over time.

II. Population Structure

<u>Age</u>

No reliable method is yet available for aging sea turtles beyond the hatching stage. Sea turtles populations are composed of state classes defined by sizes which are species and perhaps population specific. Differential growth rates presently prohibit the extrapolation of age from size data. Generally, populations are considered to include at least six life history stages. These stages are:

a) egg
b) hatchling
c) yearling
d) juvenile
e) sub-adult
f) adult

A frequency distribution of numbers per stage are derived for eggs, hatchings, and adults from counts. The number of recruits vs. remigrants is derived from tag-recapture data and is generally known and also incorporate corrections for tag loss. It is assumed all nesting females without tags or evidence of previous tagging are recruits. No estimates for the numbers of yearling, juveniles or sub-adults are available. Thus, for any nesting season, numbers of eggs, hatchlings and nesting females are determined.

Sex Ratios

Sex ratio of the egg, hatchling and sub-adult stages are unknown. Currently ratios are determined for adults from trawl catches, and the assumption is made that the probability of capture is equal for males and females. Aerial pelagic surveys MAY be used to determine sex ratios, assuming mature females are at least some predetermined carapace length. Adult males can be identified by the presence of a tail which extends beyond the rear of the shell. However, while we know females do not breed every year, we do not know if males are also periodic participants. Thus, at any given time during the breeding season the number of males sighted may represent all the breeding males for that breeding group. Movements of males are unknown. Whether males return to the same breeding area or not is also not known. However, aerial surveys can be used to derive relative estimates (an index) of adult males and females. While the dynamic properties of a population are primarily dependent upon the number and characteristics of the females, when considering the effect of exploitation, the number of males present is also important. For example, exploitation which focuses on sub-adults, could effect the number of male recruits present in the population for several years because age at sexual maturity is not known. Thus, the lag time for hatchlings to become recruits (generation time) is not known.

III. Abundance

A. Eggs and Hatchlings.

The numbers of eggs deposited in a given year is derived from direct counts or by the product of some mean value for numbers of eggs per nest and the total numbers of nests. The numbers of eggs deposited per female is used to estimate reproductive rate. Tag-recapture studies give estimates of the numbers of nests per female, which multiplied by mean number of eggs per nest gives a fertility value (m_x = reproductive rate).

I know of no other way to derive estimates of numbers of hatchlings other than by on-site counting. Either hatchlings are counted upon emerging from the nest or the number of hatched eggs are totalled. Often when percent hatch is known this value is multiplied by total eggs to give total hatchlings.

Females do not nest every year, rather most nest every 2,3 or 4 years. If the cycle is known for a given "population" or breeding colony the multiplication of the total number of eggs and hatchlings produced in one year times the number of years in a cycle gives a first approximation of the total number of eggs and hatchlings produced in a breeding population for one breeding cycle (i.e. 2,3 or 4 years) of data are available, mean values and variances may be calculated. Note that such estimates for hatchlings are only relevant for the stage prior to individuals entering the water.

B. Nesting Females

A quick estimate of the total numbers of nesting females ($\hat{N}_n$) in a given season is derived by taking the total number of nests and dividing by the average number of nests and dividing by the average number of nests or clutches per female (Fig. 1). In general these data are available by state or nesting beach. Multiplying by the interbreeding cycle (2,3 or 4 years usually) gives a rough estimate of total number of nesting females Numbers can be corrected (weighed) when the interbreeding cycle is enumerated by frequency of individuals/cycle. These data are derived from tag-recapture studies, and are generally available for <u>Caretta caretta</u> (loggerhead) and <u>Chelonia mydas</u> (Atlantic green turtle). Tag recapture studies have also been used to correct for the total number of nests and eggs per clutch per recruit vs. remigrant which may differ significantly by area or year. The information required to correct for recruit vs. remigrant clutches and the numbers of recruits vs. remigrants, are derived from tag-recapture studies. Hence, tag-recapture studies alone give direct estimate of the numbers of total nesting females/year which can be further differentiated into total recruits (individual without tags or evidence of tags) and total remigrants per year (individuals with tags or evidence of tags).

Aerial surveys of nesting beaches are used to determine relative nesting activity through any given season. Utilizing these data for estimation of the total numbers of nesting females presupposes that only those crawls resulting in nests are counted (true crawls). An experimental design for the dates and numbers of flights is a difficult task. All true crawls must be counted and true crawls are generally differentiated from "false" crawls by an additional field effort on the beaches (ground truthing). In areas of high nesting density it is often difficult to separate crawls and counts may be grossly inaccurate. When flights are made to correspond with tidal activity (about every two weeks) to insure only fresh crawls are counted, the data are biased by the probable internesting interval (12-16 days) and the nests of the same females may be counted during each flight. These problems preclude use of present aerial techniques at this time for obtaining relatively accurate estimates of the nesting population size. Again, the aerial effort assumes knowledge of the numbers of clutches per female which are derived from tag-recapture studies.

Because of lack of knowledge on dispersal of sea turtles, single season estimates (of N_n) are only that. Whether loggerheads are site-specific (i.e. return to nest at the same beach within a season or successive season) has not been conclusively demonstrated as has been for green turtles (*Chelonia mydas*). This will probably be determined with continued tag-recapture studies of loggerheads. Figure 2 summarizes the factors influencing the number of nesting females in a population.

IV. Dispersal and Migration

Caretta caretta is the most conspicuous species in our area. At this time it is not known what immigration and emigration rates are for *C. caretta* (zero or non-zero). Movements of females are generally from a feeding ground to a nesting beach. Routes of these breeding migrations are not known. Assuming that at this time loggerhead breeding colonies have been saturated with tags that all nesting turtles are encounted and there is no immigration or emigration, then any animal that arrives at a nesting beach without a tag or evidence of tagging is considered a recruit or "neophyte" (first time nester). Hence, the population may be treated as closed and all additions to the breeding population are derived from recruitment.

Probably the only way to define migratory routes and movements of animals offshore will be through observers aboard commercial fishing vessels and pelagic aerial surveys. These appear to be the only ways to determine where animals are spatially distributed by size class and by time.

V. Mortality and Survivorship

Mortality of "eggs" is determined by using percent hatch. Usually a mean value is derived with some measure of variability. Again, sampling is such that percent hatch is considered constant over space, time, female, etc.

Hatching mortality is known only for animals in transit from nest to water and derived from observation (counts). It is assumed that mortality is high until some critical size is attained. A survivorship curve may follow a negative exponential with approximately 1% of the hatchlings successfully breeding at least one time.

Mortality of sub-adults may be derived from catch per unit effort data. However, this statistic presently is derived from the presumed survivorship curves.

VI. Recruitment

Recruitment is estimated by knowing the total stock size. When tag-recapture data are available, the ratio of recruits (animals without tags) to total population size may be calculated. Multiple tag-recapture data are useful in elucidating trends. The effect of year to year fluctuations in recruitment may be a function of population density and/or environmental factors. Whether these factors are additively or multiplicatively synergistic is unknown. Again the problem of associating sub-adults with a given breeding population is a complicating factor.

VII. Conclusions

Table 1 summarizes the primary gaps in our knowledge of marine turtles which are relevant to population analysis. Table 2 summarizes the type of studies which result in computation of population parameters used in population analysis. If a population is not restricted to females, then well-designed pelagic aerial surveys give the best estimates of total numbers, generally without differentiating by sex. Thus a biomass estimate is derived, bounded by some visibly minimum size class. Figure 3 summarizes the possible decision making process to determine the neccessity of pelagic aerial surveys. At present there is no information on dive times in turtles. Estimates derived from present pelagic survey techniques need to be supplemented with research on surface and diving times, without which the density estimates so obtained probably represent minimum numbers.

In summary, the data on hand for sea turtles includes:

1. Number of eggs deposited each season per female (m_x).
2. Percent hatch (i.e. egg to hatchling survivorship).
3. Number of nesting females per season.
4. Interbreeding cycle and numbers of females per cycle (usually 2,3 or 4 years).
5. Estimates of recruitment (no tags vs. tags, corrected for tag loss).

Given these data and resulting parameter estimates (i.e. statistics), partial population analysis can be completed at this time. We know that for a female to replace herself, one female hatchling must survive to breed. Given a 1:1 sex ratio of hatchlings, the value of survivorship from hatchling to recruit (p_1) is approximately .01 (1 in 100) for replacement.

From several years of tag-recapture data we have already estimated recruit to remigrant survivorship (p_2). However, we cannot partition total mortality into natural vs. "other", for remigrants. If we assume turtles represent a stable age (stage) distribution and $p_1 = .01$, if the breeding population is numerically declining than $p_1 < .01$. Both possibilities can be examined and used to derive a relative estimate of mortality due to fishing.

Another way to investigate a marine turtle population with existing data on nesting females and fertility rates is to begin by assuming some range in age of sexual maturity and working backwards. That is, complete a cohort analysis in reverse. If incidental catch data are available, then this reverse cohort analysis can incorporate an estimate of fishing mortality. The choice of age of sexual maturity at this time is a representative range (e.g. 6-13 years for *Chelonia mydas*). Because this age represents generation time, this age determines recruitment rate and hence will effect the estimate of numbers of sub-adults in the "population".

Table 1 summarizes the primary discontinuties in data preventing complete population analysis. Note for both above suggested methods certain assumptions must be made. When more data are available, through iteration more accurate estimates of numbers and rates will be derived.

Where do these "more data" come from? Table 1 lists the major unresolved problems which prohibit elimination of the several assumptions which must be made for population analysis (i.e. sex ratio; age of sexual maturity; site specificity, etc.). It appears likely that continued tag-recapture efforts will solve (for breeding females) the second 2 problems (in part or whole). Scientific observers aboard commercial fishing vessels could improve these data considerably. Assuming that scientific trawling is impractical (i.e. not cost effective), then tag-recapture studies can be supplemented with well-designed pelagic aerial effort, stratified by place and time given an expected distribution of the animals. Again, estimates of abundance are conservative because bottom time versus surface time of marine turtles is not presently known. The decision to complete aerial surveys to determine population limits, numbers, distributions and movements is summarized in Figure 3.

The intent of this report is to identify data needs directed towards population analysis. While incomplete data exist, partial analysis is possible now given the data on hand. Immediate efforts should be directed to a) defining populations and b) determining the shape of the survivorship curve.

Fig. 1 .The following scheme summarizes how $\hat{N}_n$ (the number of nesting females) can be derived from currently available data. Assuming a 1:1 sex ratio, $2\hat{N}_n$ gives the number of breeding turtles($\hat{N}$).

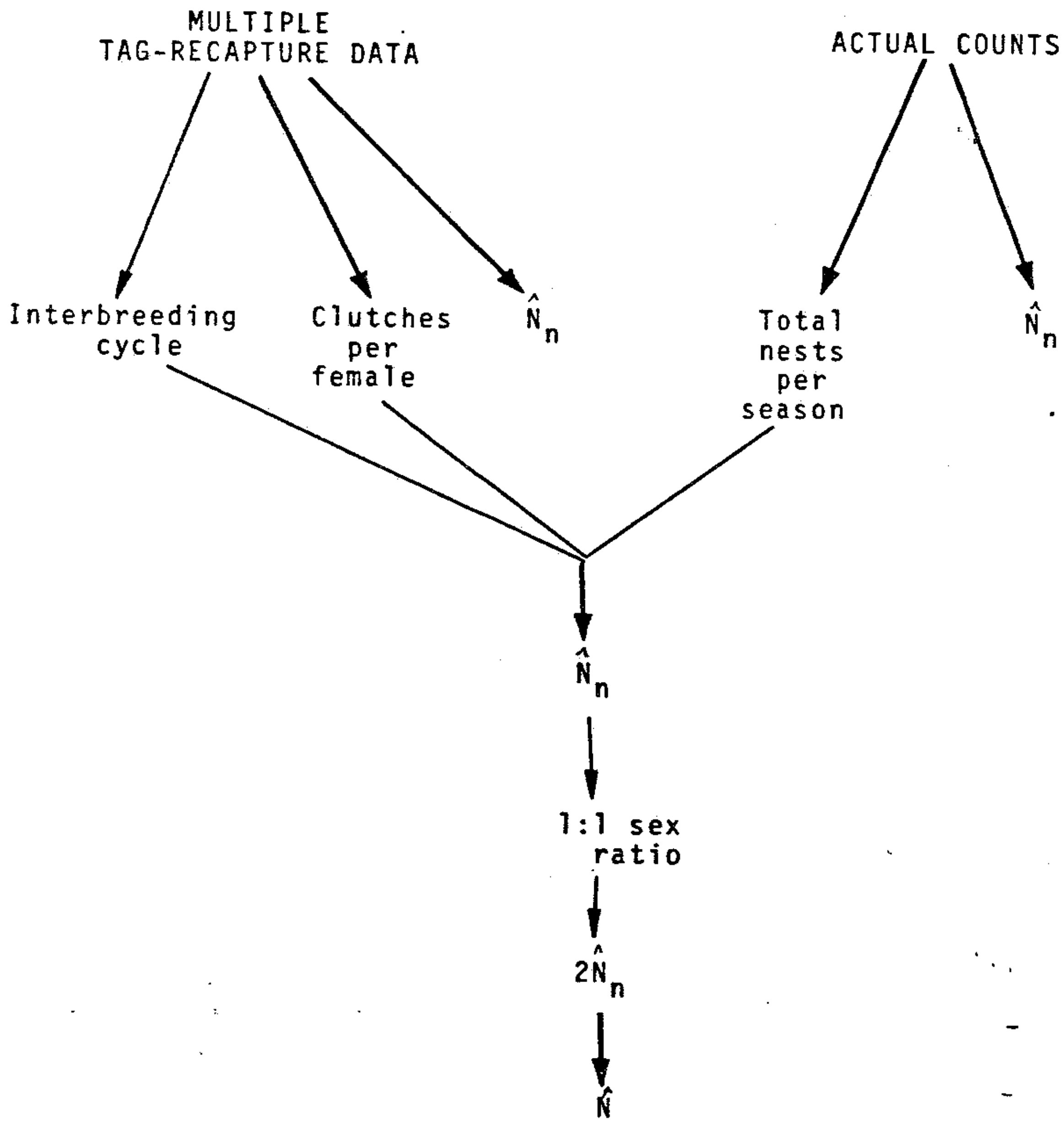


Fig. 2 Major factors influencing size of breeding or nesting population or "sub-populations". All factors but mortality estimates for the sub-adult stages can be determined from data on hand.

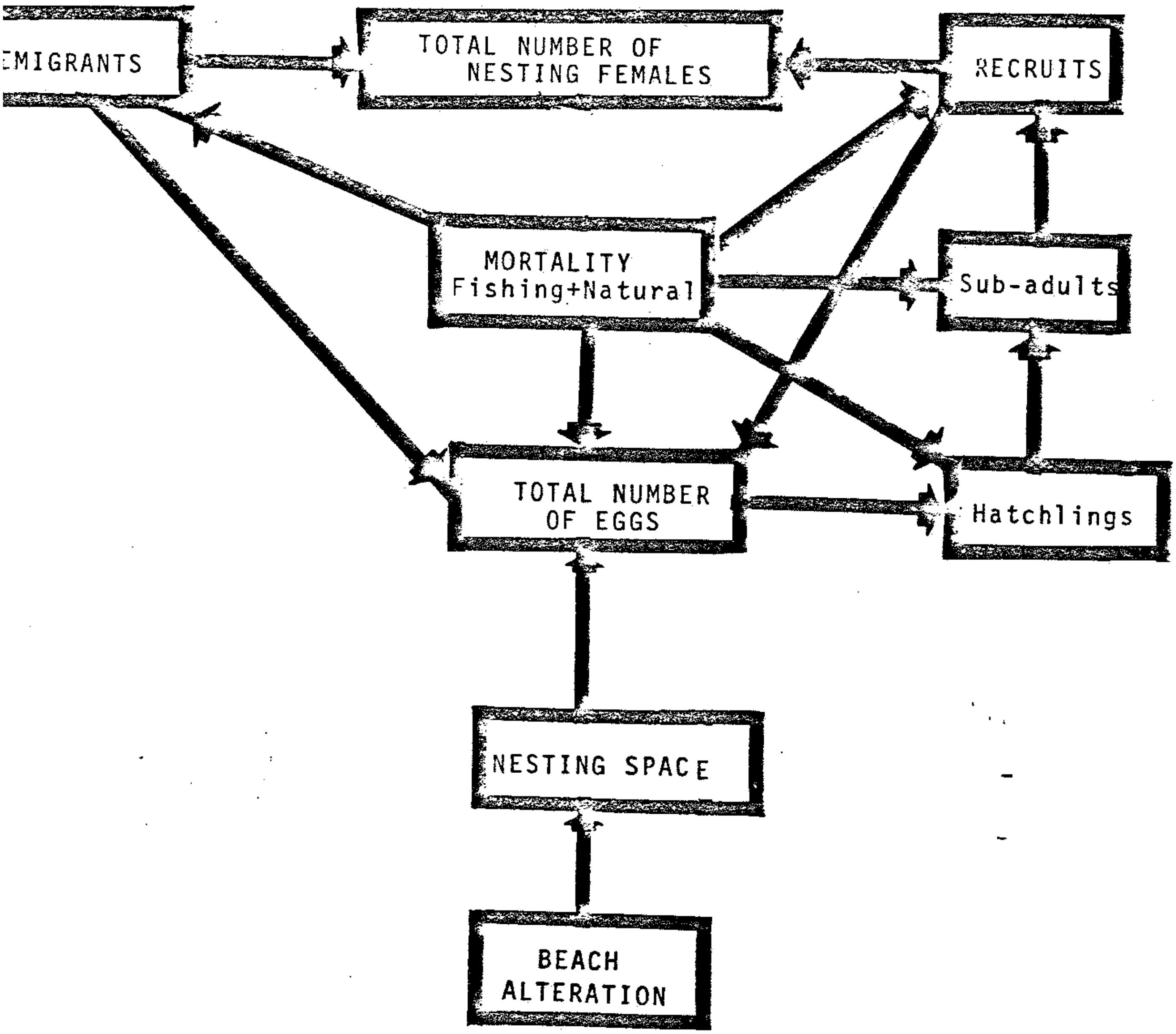


Table 1 Primary Unresolved Problems Relevant to Turtle Population Analysis:

1. Defining the population spatially and temporally for each or all stages.

2. Determining migration routes and dispersal patterns of both sexes, for all stages.

3. Effect of population density and environmental alteration on the dynamic properties of the population.

4. Sex ratio for all stages.

5. Lack of data on sub-adult stage including age-growth data and age of sexual maturity; both relevant to determination of actual sub-adult survivorship.

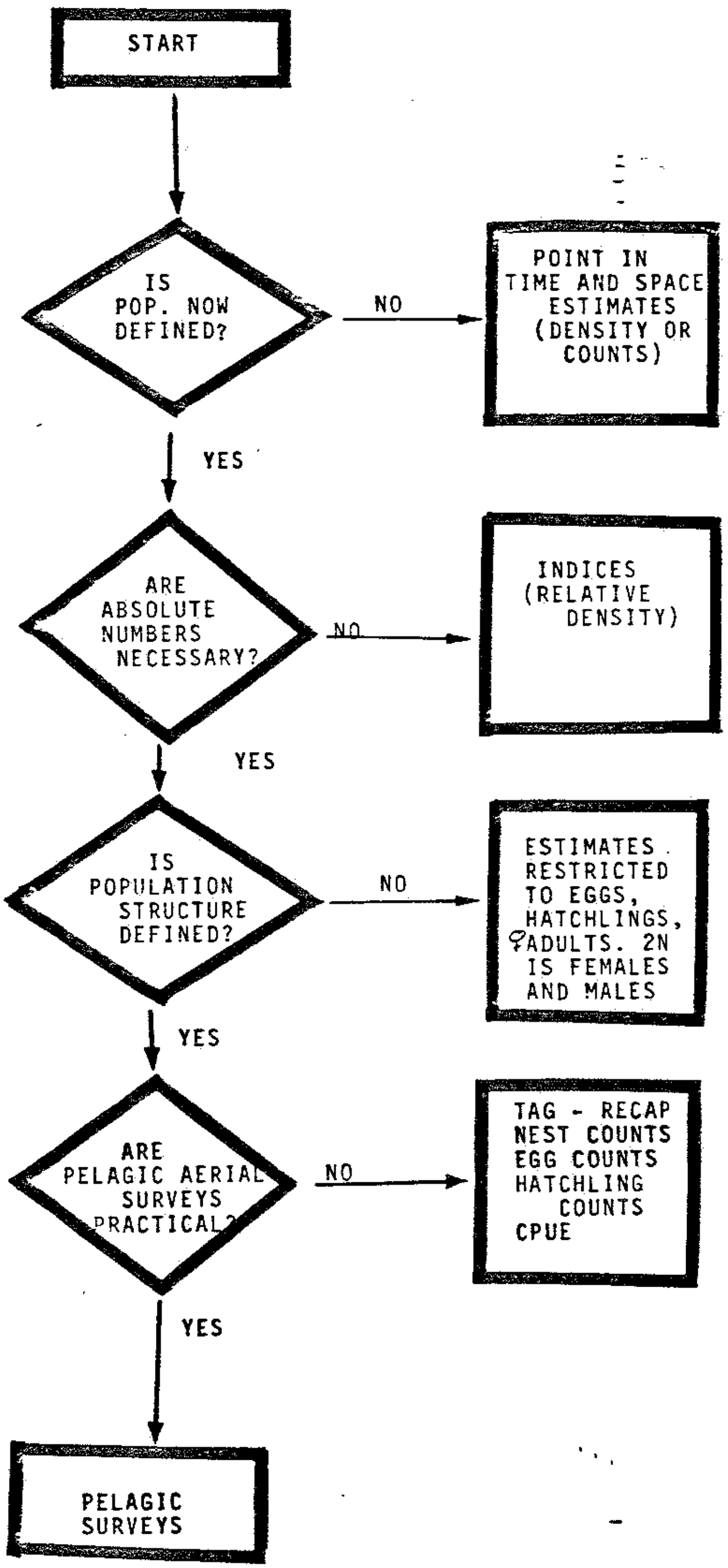
Table 2 Summary of information resulting from field efforts.

DATA SOURCE	AVAILABILITY	RESULTS
I. TAG-RECAP STUDIES	1. yes*	1. Estimate of $\hat{N}_n$
	2. yes	2. Estimate of adult survivorship
	3. yes	3. Recruitment rate
	4. yes	4. Point to point movements
	5. yes	5. Growth of adults
	6. yes	6. Reproductive rates
II. CATCH DATA	1. no**	1. Population structure
	2. no	2. Estimate of fishing mortality, F by size class
(catch composition and cpue)	3. yes	3. Distributions of turtles relative to fishing effort
	4. yes	4. $\hat{N}_h$
III. GROUND COUNTS	1. yes	1. Index of nesting activity
	2. yes	2. Relative nesting density
	3. yes	3. Egg survivorship, $\hat{N}_e$
	4. yes	4. Hatchling survivorship from nest to water, N_h
IV. AERIAL SURVEYS	1. no	1. Estimates of density $(\hat{D})$
	2. no	2. Population boundaries (i.e. distributions by species, size class, time, space)
	3. no	3. Movements and migratory routes
	4. no	4. Estimate of total population size (i.e. bounded by minimum carapace size class)

*yes indicates that data are now available

**no indicates that data are not present and further research effort is needed

Fig. 3 Decision tree to determine the necessity of pelagic aerial surveys.



APPENDIX

An Outline of Parameters commonly Estimated in Population Analysis

Population Analysis

I. The Population

   A. Limits

   B. Breeding system

   C. Parameter choice

      1. age specific survival
      2. age specific fertility, fecundity
      3. frequency distribution by age
      4. sex ratio
      5. numbers or density estimates-
      6. correlate statistics
         a. birth rate
         b. death rate
         c. rate of numerical change

II. Age

   A. Structure

   B. Distribution

III. Abundance

   A. Indices (relative density)

   B. Absolute density

      a. total counts (censuses)
      b. guesses
      c. sampled counts
      d. selective additions-removals
      e. non-selective additions-removals
      f. corrected or weighted indices

IV. Dispersal and Migration

A. Patterns

B. Pattern detection

C. Effect on parameter estimation

V. Fecundity

A. Season of births

B. Frequency of births

C. Sex ratio

VI. Mortality

A. Patterns

1. selective removals
2. non-selective removals
3. seasonality

B. Partitioning

1. natural
2. fishing

VII. Recruitment

A. Dependence on density of adult population

B. Estimation of rates

VIII. Relationship between parameters

A. Rates of increase or decrease

1. finite
   a. realized
   b. potential

2. instantaneous
   a. realized
   b. potential

VIII. Relationship between parameters (cont.)

B. Evaluation of demographic vigor

1. stability of parametal relationships

2. stability of population size

3. stability of population structure

a. interpretation of age distribution