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Report of the 2nd Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales

International Whaling Commission

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Contents

Executive Summary

This Workshop was a technical follow-up to the 2014 Workshop that had fully reviewed the available information on stock structure, abundance, biology etc. with a view to developing an initial modelling framework for gray whales throughout the North Pacific. The Workshop reviewed the progress made intersessionally on recommendations made at the 2014 annual meeting of the Scientific Committee. These included additional work on the comparison of photographic and genetic catalogues, development of Single Nucleotide Polymorphisms (SNP) assays for use with gray whales to improve genetic analyses, additional work including a new research cruise to improve the sample sizes (genetic and photo-identification) for the northern feeding areas, additional telemetry work, improved abundance estimates for PCFG (Pacific Coast Feeding Group) whales, improved early catch history data for the western North Pacific and better estimates of ship strikes and bycatches throughout the North Pacific. Focus within the Workshop was on how the additional information could feed into the modelling framework, now and in the future. A key analysis identified at the initial workshop was to examine the existing data to see what bounds could be put on the proportion of animals breeding in the western North Pacific as opposed to those regularly feeding in the western North Pacific. Following an analysis by Cooke (SC/A15/GW2), the Workshop concluded that if such a breeding ground exists, then the proportion of the Sakhalin animals that use it is probably lower, and possible considerably lower than 63%. The Workshop made a number of recommendations for work to be undertaken that would narrow the confidence range for this.

The Workshop's primary focus was to review the excellent intersessional work undertaken by Punt (SC/A15/GW1) to produce initial specifications and runs for the an age- and sex- structure population dynamics model. The Workshop reviewed progress and in particular examined the parameterisation of the hypotheses allocated as priorities for examination at the 2014 Scientific Committee meeting and updating the modelling framework. This involved further schematic visualisation and clarification of the hypotheses and work to develop the catch mixing matrices and finalisation of the datasets by hypotheses. The Workshop also refined the manner in which uncertainty will be refelected in the trial structure and developed a workplan to allow initial results to be considered at the 2015 Scientific Committee meeting. The importance of developing a plan to update the IUCN/IWC Conservation Management Plan at the 2015 was also noted.

The Workshop was held at the Southwest Fisheries Science Center (SWFSC), La Jolla, California, from 1-3 April 2015. The list of participants is given as Annex A.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan welcomed the participants to La Jolla and thanked Weller and the Southwest Fisheries Science Center for the excellent facilities. He noted that this was primarily a technical Workshop to review the modelling work recommended by the Scientific Committee at the 2014 Annual Meeting in the light of the work undertaken during the first workshop (IWC, 2015c).

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Reeves, Brandon, Cooke, Lang and Punt were appointed rapporteurs with assistance from the Chair and others as appropriate.

1.4 Adoption of Agenda

The adopted agenda is given as Annex B.

1.5 Documents and data available

The list of documents is given as Annex C.

2. SHORT REPORT ON PROGRESS ON 'NON-MODELLING' RECOMMENDATIONS

The Workshop assessed progress on implementation of the recommendations from the previous (April 2014) gray whale workshop (IWC, 2015c).

2.1 Preliminary comparison of identified gray whales in Mexico, off central California and in the PCFG with a focus on mothers and calves

The objectives of this recommendation related to improved assessment of internal recruitment into the PCFG (Pacific Coast Feeding Group) (IWC, 2013a), improved estimates of calf survival and better determination of the number of known reproductive PCFG females that have been biopsied.

Weller reported that his group had completed preparation of a catalogue of mother-calf pairs photographed from shore off central California (Piedras Blancas) during 2012-14 and this was to be posted on the SWFSC website within the next few weeks. Jorge Urbán and John Calambokidis are expected to then compare their catalogues to the SWFSC catalogue with the principal goal of evaluating recruitment into the PCFG. The Workshop **recommends** that Weller notifies Urbán and Calambokidis when the catalogue is available and works with them to determine a realistic timeframe for completing the comparisons.

Once the results are obtained, further work will be required to develop an approach for using the results to derive mixing rates. It was noted that the three years (2012-14) to be considered may be insufficient to obtain reliable 'long-term' averages.

2.2 Comparison of photographs (and genetic material) of gray whales from areas of the Okhotsk Sea and elsewhere in Asia with the Sakhalin and Kamchatka catalogues

No formal progress had been made on implementing this recommendation which will, once completed, enable better understanding of stock structure and movements on the western side of the Pacific. However, the Russia-US team had previously reported photographic matches between Sakhalin and Paramushir Island (northern Kuril Islands) and the Shantar archipelago in the western Okhotsk Sea and at Bering Island in the Bering Sea (IWC, 2015). Tyurneva (IBM, Vladivostok) has also reported on some photographs from areas of the Okhotsk Sea other than Sakhalin and eastern Kamchatka ({Tyurneva, 2012 #46066}). Donovan will contact Tyurneva in this regard.

With respect to genetic material, Pastene reported (pers. comm.) that: (a) tissue samples from five animals (+ a calf) of the six analysed in Kanda *et al.* (2010), which were thought to have been lost in the tsunami, do still exist, since sub-samples have been discovered in his Tokyo laboratory; and (b) the only Russian samples held in Japan are the seven analysed in SC/62/BRG5 (these were lost in the tsunami). Donovan will to contact Ilyashenko regarding the 'about 150 samples' from Russia referred to in IWC (2015c). Brownell agreed to consult with Yamada on potential material that either has gone to or is planned to go into museum displays (or at least collections) in Japan.

The Workshop **recommends** that Weller and Brownell modify the table from Kato *et al*. (2014), adding new records and supplementing information on included records, as appropriate. This should include confirmed non-matches or probable non-matches, as well as matches.

2.3 Development of Single Nucleotide Polymorphisms (SNP) assays for use with gray whales
This recommendation would *inter alia* allow integration of genetic data between laboratories and over time and facilitate work with low quality samples such as bone and baleen. The Workshop was informed of two next generation sequencing projects that are planned to begin this year.

Bickham reported that, in collaboration with Andrew DeWoody of Purdue University, a project to sequence the genome of four gray whales (a male and a female each from the Northern feeding ground and the Sakhalin feeding ground) will begin in 2015. Once genome sequencing is complete, sites that are variable (SNPs) within and among individuals will be identified, and SNP assays will be designed to genotype additional samples (n = 35) collected from gray whales off Sakhalin Island at ~100 of these SNP loci. This work will be completed in 2015, and the results will be presented to the IWC Scientific Committee in 2016.

In addition, Lang reported that SWFSC plans to conduct SNP genotyping of ~200 samples of gray whales from the Northern feeding ground, the PCFG and Sakhalin. These genotypes will be generated using a "genotype-by-sequencing" approach based on a double digest restriction-site associated DNA sequencing protocol. Expected results include the identification of hundreds of SNP loci in gray whales; the data is anticipated to be available in spring 2016. In both studies, the resulting sequence data (e.g., genome and primer sequences in the Bickham study, nuclear sequences encompassing SNPs in the SWFSC study) will be published to allow gray whale researchers in other labs to design SNP genotyping assays for use with traditional and/or next generation sequencing approaches. In addition, Bickham and Lang plan to work together to review the pooled data and select a subset of SNP loci that can be recommended for inclusion in future genetic studies of gray whales, in order to facilitate combining data across labs and over time.

The Workshop **welcomed** this excellent progress and thanked Bickham and Lang for their efforts to ensure this recommendation is being implemented.

2.4 Increased sample size and coverage from the eastern North Pacific
This recommendation will improve comparisons amongst feeding areas and improve stock structure hypotheses for future modelling exercises.

The Workshop considered what additional material has become available (photographs and genetic samples) since the last workshop (IWC, 2015c), table 1).

Potential sources include the North Slope Borough, Alaska (Lang will check on additional data since April 2014), the Chukotka hunt (Brownell will check on what was reported at the last SC meeting in May-June 2014), and Urbán's programme in Baja California (Lang will check with Urban).

2.4.1 2015 Research cruise
Perryman reported that the SWFSC may get access to two months of ship time for a cruise starting in Ketchikan, Alaska, and working south through portions of the Gulf of Alaska, possibly to begin in August 2015. Collection of gray whale photographs, biopsies and possibly deployment of satellite tags, particularly in the area between Kodiak Island and northern California (i.e. the broadest extent of the putative PCFG range), would be a primary objective of the cruise.

The Workshop **welcomed** this news and **recommends** that a cruise of this nature be conducted, and highlighted the value of such work in filling important data gaps, particularly with respect to better understanding the dynamics of the PCFG.

The Workshop also **recommends** that gray whales on northern feeding grounds (e.g. Alaska and Chukotka) are photographed and existing and new photographs are shared with catalogue holders for evaluating the mixing of PCFG and WFG whales on northern feeding grounds.

2.5 Continued telemetry studies
This recommendation was a reiteration of the need for additional telemetry work (e.g. IWC, 2012; 2015), especially in feeding areas such as Kamchatka, Sakhalin and Chukotka. Such studies provide information on habitat use, migration routes, vulnerability to anthropogenic removals etc.

The Workshop noted that no further telemetry work with gray whales had taken place since April 2014. Mate reported that the analysis and writing up of previous telemetry studies, including those summarised in IWC (2015c) is progressing well and will be published soon in *Biology Letters*. The proposed telemetry work off

Sakhalin in summer 2015 (IWC, 2015c) will not take place due in part to the extensive seismic survey work taking place and the focus on monitoring and mitigation work. It is hoped that more telemetry work will take place in off Sakhalin in 2016 but as yet there are no confirmed plans.

The Workshop **reiterated** its previous recommendations for continued telemetry studies (and see the discussion under Item 3.1. and the recommendations under Item 5)

2.6 Improved abundance and trend estimates for the PCFG by identifying and using additional photographic sources

It is important to know the degree to which there was large-scale recruitment into the PCFG during the period prior to around 1998 (which would have to have been from an external source) to evaluate the status of the PCFG. Laake reported that some progress has been made and the Workshop **reiterates** its previous recommendation (IWC, 2015c).

2.7 Improved estimates of western North Pacific catches 1890-1910

The Workshop recognised that the present modelling exercise begins in 1930 i.e. that improved 1890-1910 catches were not a high priority in the short term but are of longer-term value.

Although little progress had been made to date on this recommendation, Brownell reported that he believed that some operational data must be available in Norwegian sources because vessels and captains during this time period were from Norway. Any study on this topic will require participation by researchers with appropriate language abilities – i.e. mainly Japanese, but also Russian and Norwegian sources will need to be checked. Brownell **agreed** to pursue with colleagues in Japan and Norway and report back at the 2015 Annual Meeting of the Scientific Committee (SC66a) in May 2015.

2.8 Improved estimates for future ship strikes and bycatches throughout the North Pacific (see SC/65b/BRG21)

Scordino reported that considerable progress had been made on this recommendation including presentation of Scordino *et al.* (2014) at the 2014 Annual Meeting (IWC, 2015b). This is discussed further under Item 4.2 and details are provided in Annex F.

3 PROGRESS REPORT ON MODELLING-RELATED ISSUES

3.1. Putting bounds on the proportion of Sakhalin whales that migrate to the eastern North Pacific

As part of the long-term study on whales off Sakhalin Island, Russia, photo-catalogue comparisons of gray whales in the western (WNP) and eastern North Pacific (ENP) have been undertaken to assess population mixing. These comparisons included:

(1) a systematic comparison of a WNP 'Sakhalin Catalogue' (i.e. comprising animals photographed off Sakhalin Island) to an ENP 'Pacific Northwest Catalogue' that consisted of images from the northwest coast of North America (Weller *et al.*, 2012); and

(2) a systematic comparison of a WNP 'Sakhalin Catalogue' and 'Kamchatka Catalogue' (i.e. animals photographed off Kamchatka) to an ENP 'Lagoon Catalogue' that consisted of images from central Baja California, Mexico.

The Sakhalin to Pacific Northwest comparison consisted of 181 and 1,064 whales, respectively, and resulted in 6 matches (Weller *et al.*, 2012). The Sakhalin to Mexico comparison consisted of 232 and 7,493 whales, respectively, and resulted in 17 matches (Urbán R. *et al.*, 2013; Urbán R. *et al.*, 2012). The Kamchatka to Mexico comparison consisted of 150 whales and 7,493 whales, respectively, and resulted in 6 matches (Urbán R. *et al.*, 2013; Urbán R. *et al.*, 2012).

SC/A15/GW2 looked at whether the available matching data could be used to place bounds on the proportion of Sakhalin whales that migrate to the eastern North Pacific, as recommended by the first Workshop (IWC, 2015b). The photo-identification matches between the Sakhalin catalogues and the 2006-12 part of the San Ignacio catalogues were used, in addition to the three successfully tagged animals in Sakhalin.

The photographic matches showed that around 90% of the Sakhalin-Mexico matches (17 out of 19) consisted of whales that were (a) 'adults' (age at least 7 by 2006) and (b) known to be alive at least until 2011.

The expected number of matches that would be found for a given value for the proportion of Sakhalin whales that migrate to Mexico depends on the annual sampling rate in Mexico. The author noted that if all the ~20,000 whales migrating past California are 'adults', then the observed number of matches is approximately equal to the number that would be expected if all Sakhalin adults migrate to Mexico. However, if the whales passing California include a substantial number of juveniles that do not enter the sampled areas in Mexico (i.e. in this case San Ignacio lagoon), then the sampling rate of adults is higher, and the number of matches is less than would be expected if all Sakhalin whales migrated to California and Mexico.

The author of SC/A15/GW2 had noted that if neither hypothesis can be ruled out at this stage, the union of the confidence limits, 0.37 to 1.0, was the current feasible range for the proportion of Sakhalin animals that migrate to the eastern North Pacific. In summary, this would imply that the data neither confirm nor reject the existence of a western breeding ground. However, if such a breeding ground exists, then an approximate upper bound for the proportion of the Sakhalin animals that use it would be around 63%.

The Workshop considered the available evidence with respect to the animals that are included in the California census data. Rice and Wolman (1971) have shown that the migration of gray whales in the eastern North Pacific is segregated by age, sex and reproductive condition. Catch data and multiple other lines of evidence show that all age and sex class segments of the population migrate past central California on their way to wintering areas off Baja. The first pulse of migrants is led by (a) near-term pregnant females, followed by (b) oestrous females and mature males and then (c) immature animals of both sexes.

While in the wintering grounds, whales are segregated by age and sex group (Norris *et al.*, 1983; Swartz *et al.*, 2006). Lagoon entrance aggregations are composed of males, non-parturient females and juveniles. By contrast, females with calves concentrate within the interiors of lagoons. This segregation of whales without calves from females with calves is an extension of the age and sex segregation seen during the spring and fall migrations (Rice and Wolman, 1971). Mate (pers. comm., IWC, 2015) had noted that 8 of 17 animals satellite tagged that were found in Mexican waters did not have any high quality locations within the lagoons.

Primarily based on information from Rice and Wolman (1971), the northward migration begins about mid-February and is also segregated according to age, sex and reproductive condition. The first phase of this northern migration includes (a) newly pregnant females followed later by (b) adult males and anoestrous females and then (c) immature whales of both sexes. The second phase consists mostly of mothers with calves. These pairs are observed on the migration route between March and May and generally arrive to the summer feeding grounds between May and June.

In the light of this information, the Workshop **agreed** that it seemed unlikely that the California census data excluded large numbers of juveniles (or indeed any classes) of gray whales. However, it also noted that the available evidence could not rule out that large numbers of animals (including juveniles) do not enter the lagoons. Thus while it concurred with the author of SC/A15/GW2 that the available data neither confirm nor reject the existence of a western breeding ground, it **agreed** that if such a breeding ground exists, then the proportion of the Sakhalin animals that use it probably lower, and possible considerably lower than 63%.

With a view to narrowing the confidence range for the proportion of Sakhalin whales that migrate east, the Workshop **recommends** the following priority analyses:

(1) that the Mexican catalogues be re-examined with a view to finding further Sakhalin matches that may have been overlooked to ensure that the underlying data best reflect the correct number of matches *and* non-matches;

(2) that the Mexican photo-id data, and particularly that for Laguna San Ignacio, be analysed using mark-recapture models with a view to estimating the size of the sampled population – this will allow improved estimates of the sampling rate – a critical parameter that affects the expected number of matches under any given migration hypothesis;

(3) that other sources of data, including the Pacific Northwest catalogue and the genetic data set held by the SWFSC, be included in updated analyses of those presented in SC/A15/GW2. Although these data sets are smaller, they will inform the estimates of the proportion of juvenile whales that participate in the migration.

Recognising that telemetry studies off Sakhalin can provide considerably more information than simply related to the proportion of animals that migrate east, the Workshop **agreed** that at least in this context, tagging of non-calf animals (<7 years) is important; the youngest of the three successfully tagged whales to date has been 10 years old. While the successful tagging of a small number of additional adults (say three) in Sakhalin would narrow the confidence interval on the proportion only modestly if all the tagged whales migrate east, the results would be revealing if one or more animals migrates to the western Pacific destination.

There was some discussion of the significance of gray whales found in Japanese waters, including a recent (March 2015) sighting that was successfully matched with the Sakhalin catalogue. It would be helpful to ascertain the relative age of these individuals (juvenile or adult). Finding mature animals off Japan at the time of the northward and southward migrations would be more suggestive of there being a western breeding ground.

3.2. Continued development of the population model for the Sakhalin feeding area

Two updates of the model had been presented to the 14th WGWAP meeting held in Sakhalin in October 2014 using (a) the Russia-US Sakhalin photo-id data 1994-2013; and (b) the Russia-US 1994-2013 data together with the IBM Sakhalin data 2003-2011 and the Kamchatka data 2006-11 (Cooke *et al.*, 2014; IUCN, 2014).

For the analysis using all three data sets, the model had been extended to allow for different stage-specific availabilities in the three data sets. This extension largely resolved the problems encountered in previous attempts to reconcile the three data sets. Juvenile animals (apart from calves) were found to be under-represented in the Sakhalin catalogues and over-represented in the Kamchatka catalogues, relative to other population components.

Both analyses yielded strong evidence of annual variability in calving rate. The analysis using the Sakhalin data alone yielded some indication of annual variation in the calf survival rate, but this effect disappeared when the Kamchatka data were included, because some of the 'missing' young animals were found in Kamchatka. The best estimate of the Sakhalin population in 2013 was 38 mature females (SE 2) growing at an average rate of 2.5% (SE 0.5%) over the previous 10 years. The best estimate of the age 1+ population in 2013 was 176 (SE 2).

3.3 Development of an age- and sex-structured model

In response to recommendations at the 2014 Annual Meeting of the Scientific Committee (IWC, 2015a), SC/A15/GW1 provided *inter alia* specifications for a sex- and age-structured population dynamics model which can represent the stock hypotheses developed during the April 2014 rangewide review of population structure and status of North Pacific gray whales (IWC, 2015b). The model allows for more than one population, each of which can have 'sub-stocks', multiple feeding and wintering grounds, and different migratory corridors. Animals can move between sub-stocks in a pulse or diffusively. The values for the parameters of the model can be estimated by fitting it to data on trends in relative and absolute abundance, as well as mixing proportions (e.g. based on sightings data). While the model itself is generic, the specifications include choices made by the Scientific Committee when an operating model was developed to evaluate alternative *Strike Limit Algorithms* for the Pacific Coast Feeding Group (PCFG) for the eastern north Pacific gray whales (IWC, 2013). An example application of the model was provided in the paper based upon one of the priority stock structures, i.e. hypothesis 3e (IWC, 2015b) and see Item 4.2 below.

The model in SC/A15/GW1 differs from that presented to the 2014 Scientific Committee (Punt, 2014) because it (a) is age- and sex-structured, (b) splits the 'North' sub-area into two sub-areas ('southeast Alaska' and 'North'[1]), and (c) considers 'feeding' (Jun-Nov) and 'movement' (Dec-May) seasons for the BCNC and CA sub-areas to account for differences in the relative vulnerability of sub-stocks to bycatch among seasons. SC/A15/GW1 uses the abundance data for the SI sub-area, as well as the estimates of abundance for the BCNC sub-area and the counts off California, and data on mixing rates from Scordino *et al.* (2014). The updated model also includes more sub-areas and seasons, but the extent to which the model can be extended is limited by available data (i.e. sub-areas lacking sufficient data are not included in the model).

The Workshop thanked Punt for developing the age- and sex-structured model and for members of the Steering Group for their comments on the model during the intersessional period.

4. UPDATE MODELLING FRAMEWORK

4.1 Review of the nomenclature for stocks, sub-stocks and sub-areas

The model in SC/A15/GW1 is complex and uses terminology (e.g. 'stocks' and 'sub-stocks') developed initially for evaluating variants of the RMP (Revised Management Procedure; IWC, 2012). Given that this may lead to misunderstanding, the Workshop **agreed** to revise and clarify some of the terminology used in the specifications of the model.

(1) *Breeding stock*. The conceptual model of gray whales in the North Pacific considers two populations or 'breeding stocks' – the 'Western' (that breeds in Asian waters) and the 'Eastern' (that breeds in Mexican waters). The analyses assume that all animals are part of one of the two breeding stocks and there is no interchange between breeding populations. The 'Western' breeding stock is extinct in some scenarios.

(2) *Feeding aggregation*. Each breeding stock can consist of one or more feeding aggregations. A feeding aggregation is part of a single breeding stock and may be associated with several sub-areas with respect to feeding and migration. Feeding aggregations move among sub-areas during the year and may be subject to catches, bycatches and other anthropogenic impacts as they migrate (as well as when they are

[1] See Item 4 for revised names of the sub-areas.

on the summering and wintering grounds). Animals from more than one feeding aggregation may be found in each sub-area. Animals may disperse permanently between feeding aggregations (but not breeding stocks). Density-dependence is assumed to operate by feeding aggregation and as a function of abundance relative to carrying capacity in the feeding sub-areas in which the feeding aggregation is found (SC/A15/GW1).

The Workshop recognised that having the same names for feeding aggregations and sub-areas as has been previously done (e.g. during the first workshop) may lead to misunderstandings. The Workshop therefore **agreed** to the following revised terminology (and see figures in Annex E):

(1) *Breeding stocks*. There are up to two extant breeding stocks (Western and Eastern).
(2) *Feeding aggregations*. The eastern breeding stock consists of up to three feeding aggregations depending on hypotheses (Western Feeding Group (WFG)[2], Pacific Coast Feeding Group (PCFG) and 'North'). There is dispersal between the PCFG and North feeding aggregations, but the WFG is demographically independent of the other two feeding aggregations (i.e. there is no *permanent* movement of animals from the North or PCFG to the WFG).
(3) *Sub-areas*. The model includes 11 geographic sub-areas to explain the movements of gray whales in the North Pacific:
    (a) Vietnam-South China Sea [VSC];
    (b) Korea and western side of the Sea of Japan [KWJ],
    (c) eastern side of the Sea of Japan and the Pacific coast of Japan [EJPJ],
    (d) off Sakhalin Island [SI],
    (e) areas of the Okhotsk Sea not otherwise specified [OS],
    (f) East Kamchatka and the Kuril Islands [EKK],
    (g) the Northern Bering and Chukchi Sea [BSCS],
    (h) Southeast Alaska [SEA],
    (i) British Columbia to Northern California [BCNC],
    (j) California [CA]; and
    (k) Mexico [M].

The model also includes two 'latent' sub-areas used to link model predictions to observed indices of abundance. These are denoted Calif-3 and BC-BCA-3.

'Catch mixing matrices' are a core component of the model of SC/A15/GW1. Several approaches have been used by the Scientific Committee to account for movement of animals across space and the consequences to them of catches and bycatches (e.g. IWC, 2014 for North Pacific common minke whales). The approach taken in SC/A15/GW1 does not explicitly model movement but rather considers the relative vulnerability of each feeding aggregation to anthropogenic removals by sub-area. Thus, the entries in the catch mixing matrices reflect relative vulnerability.

To illustrate this, consider the catch in which two feeding aggregations of sizes 100 and 900 are found in a sub-area. If the values in the catch mixing matrix for this sub-area for these feeding aggregations were 1 and 1 respectively, the probability of a catch being from the first feeding aggregation would be 0.1 = (=100*1/[100*1+900*1]). In contrast, if the values in the catch mixing matrix for this sub-area were 1 and 0.1 respectively, the probability of a catch being from the first feeding aggregation would be 0.52 = (=100*1/[100*1+900*0.1]).

It is important to note that one element of the catch mixing matrix for each sub-area must be 1 as the elements of the catch mixing matrix are relative scalars; multiplying all of the entries of the catch mixing matrix by any constant would not change the relative vulnerability of each feeding aggregation.

4.2. Summary of priority stock structure hypotheses from first workshop

The three priority stock structure hypotheses selected by the Scientific Committee at the 2014 annual meeting (IWC, 2015b) are summarised below.

(1) Hypothesis 3a. Although two breeding stocks (Western and Eastern) may once have existed, the Western stock is assumed[3] to have been extirpated. Whales show matrilineal fidelity to feeding grounds, and the Eastern stock includes three feeding sub-stocks: PCFG, Northern Bering Sea (NBS)/Southern Chukchi (SCH)-Northern Chukchi-Gulf of Alaska ('Northern') and WFG.

[2] The WFG is a feeding aggregation which is indexed by the mark-recapture estimate for the Sakhalin sub-area.
[3] By the present Workshop; symbols used to represent the movements of the Western breeding stock have been removed in the relevant figures in Annex E.

(2) Hypothesis 3e. Identical to hypothesis 3a except that the Eastern breeding stock is extant and feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula. All of the whales feeding off Sakhalin overwinter in the eastern North Pacific.
(3) Hypothesis 5a. Identical to hypothesis 3a except that the whales feeding off Sakhalin include both whales that are part of the Western stock and remain in the western North Pacific year-round, and whales that are part of the Eastern stock and migrate to the eastern North Pacific.

The analyses in SC/A15/GW1 were based on hypothesis 3e. The specifications for this stock structure hypothesis in SC/A15/GW1 had been modified in the light of input from the members of the Steering Group (IWC, 2015b). In particular:

(1) The large 'North' feeding group has been split into a BSCS sub-area and an SEA sub-area. The SEA sub-area was further subdivided into feeding and movement seasons (June – November and December – May respectively). The rationale for this change was the presence, based on telemetry and photo-identification data, of PCFG animals in SEA. There is bycatch in this sub-area which needs to be correctly allocated to feeding aggregation.
(2) The CA sub-area was divided into feeding and movement seasons given different relative proportions of PCFG feeding aggregation and other whales in this sub-area seasonally.
(3) North and Sakhalin animals were allowed to move to the BCNC area. This is consistent with telemetry and photo-identification data for the migration season which suggests that non-PCFG animals are in this sub-area.
(4) A California-survey sub-area was added to the model to allow it to be fitted to the California estimates of abundance. The mixing parameters for this area reflect the proportion of each feeding aggregation that passes the counting platforms and hence do not reflect the relative fraction of time animals from each feeding aggregation spend in this sub-area.
(5) The link between the North sub-area and the EJPJ sub-area was ignored in the absence of data to demonstrate a linkage.

In discussion, it was noted that the KWJ migratory sub-area should be considered separately from the EJPJ migratory areas. The last sighting of a gray whale in Korean waters was in 1966 (Park, 1995), despite recent survey effort in Korean waters during the winter seasons (Kim *et al.*, 2013). Given this lack of recent sightings, it is likely that this migratory corridor is no longer used (Weller and Brownell, 2012). Thus it was **agreed** that the KWJ sub-area should be modelled as separate from the other two migratory routes where post-1966 records exist (Kato *et al.*, 2014).

In previous representations of all three hypotheses, occasional movements of whales from the North feeding sub-area were assumed to occur to the migratory routes off both coasts of Japan. Any whales moving between these two sub-areas would likely travel through the waters off eastern Kamchatka; thus this link was redrawn to more accurately represent any such movements [sub-area EKK].

Photo-identification analyses have identified one individual that was photographed off Barrow (Alaska) that had been previously sighted in multiple seasons within the PCFG range (the BCNC sub-area; (Calambokidis *et al.*, 2012). Although the limited photo-identification effort off Barrow and more generally within the North feeding sub-area makes interpreting the significance of this finding difficult, the Workshop **agreed** that the scenario of occasional movements between BCNC and the North sub-area should be included in the stock hypotheses (see Item 4.4).

4.3 Finalise datasets by stock structure hypothesis

4.3.1 Catches

The model incorporates direct catches (commercial and aboriginal) as well as bycatches and ship strikes (see IWC (2011) and the 2014 workshop IWC (2015b). SC/A15/GW1 had modelled bycatch for the eastern sub-areas based on the estimates provided by Scordino *et al.* (2014) and had also included the few reported bycatches for Japan (1 in 1955, 1 in 1970, 1 in 1996, 4 from 2005-07), Korea (0) and China (1 in 2011) in the 'catch' series for these areas. The Workshop reviewed the catch series and revised them to reallocate the bycatches off Japan, Korea and China from the catch time-series to the bycatch time-series (a full updated table will be developed at the 2015 Annual Meeting). The Workshop also corrected some errors in the catches used in SC/A15/GW1.

The Workshop **recognised** the considerable uncertainty associated with estimation of bycatches (and ship strikes), as is always the case (IWC, 2013b). Annex D lists the available information on bycatches: (a) numbers of bycaught animals observed and reported as dead due to entanglement or entrapment by sub-area, and (b) estimates of total reported bycatch mortality assuming all injured animals will die. Annex D also lists available data on ship strikes of gray whales. Not all dead bycaught (or ship struck) animals will be recorded. There are no direct estimates of reporting ('carcass recovery') rates for gray whales. Punt and Wade (2010) estimated that only 3.9-13% of gray whales that die in a given year end up stranding and being reported, while a meta-analysis by Carretta *et al.* (in review) indicated that between < 1% and 33% of animals that die from bycatch and other causes end up stranding and being reported. Upon reviewing the available information, the Workshop considered that the best proxy for the reporting rate for bycaught and ship-struck gray whales off the west coast of the USA was 0.22 (95%CI 0.17 to 0.30) which had been estimated for coastal bottlenose dolphins in California.

For modelling purposes, the Workshop **agreed** to conduct analyses in which the bycatches and ship strikes (combined) were set to the observed mortality (minimum count or estimate) and in which this was multiplied by 5 to account for underreporting (the 'best' estimate); additional sensitivity tests may be conducted at a later date. The Workshop noted that the higher estimates of bycatch/ship strike may be inconsistent with observed numbers and trends in abundance of feeding aggregations or populations and this may provide information on the plausibility of scenarios investigated. It also **agreed** that development of series of higher estimates of removals by factors other than direct catch might be warranted, but that would be deferred until the additional model results were available.

Table 1

Mixing rates by feeding aggregation by sub-area and season for the Eastern breeding stock.

Feeding Aggregation	Season	Sub-area	Areas Used for estimates	Total Observations	Total Sightings	Mixing proportion
WFG	Migratory	BC-NCA	All PCFG except SVI, SJF, and NCA	6	1626	0.00369
PCFG	Migratory	BC-NCA		150	469	0.319829
North	Migratory	BC-NCA		319	469	0.680171
PCFG	Migratory	CA	CCA-SCA	3	33	0.090909
WFG	Migratory	CA		0	33	0.002[a]
North	Migratory	CA		30	33	0.909091
PCFG	Feeding	CA	CCA-SCA	13	43	0.302326
North	Feeding	CA		30	43	0.697674
PCFG	Feeding	BC-NCA	NBC-NCA	13623	14446	0.943029
North	Feeding	BC-NCA		823	14446	0.056971
PCFG	Feeding	SE Alaska	SE Alaska	19	34	0.558824
North	Feeding	SE Alaska		15	34	0.441176
PCFG	Feeding	Kodiak	Kodiak	32	176	0.181818
North	Feeding	Kodiak		144	176	0.818182

[a] Value from Moore and Weller (2013)

4.3.2 Mixing rates

The primary data source used to estimate the estimable parameters of the catch mixing matrices (denoted as γ values) are estimates of the relative proportion of animals from each feeding aggregation in each sub-area. These estimates pertain to the relative 'vulnerability' to removals rather than simple presence i.e. *inter alia* they take time present in an area into account. Scordino *et al.* (2014) estimated the relative vulnerability of PCFG compared to other feeding aggregation animals in several sub-areas in the eastern Pacific and these estimates were included in the analyses of SC/A15/GW1.

The Workshop updated the estimates from Scordino *et al.* (2014) to provide estimates for more feeding aggregations, sub-areas and seasons. This involved extracting the number of PCFG, WFG, and North feeding aggregation whales from the Cascadia Research Collective's database of sightings of catalogued whales. A sighting for this analysis was defined as one sighting of a unique whale per day, i.e. a single whale that was observed multiple times in a single day was only counted as one sighting. Mixing rates were computed as the number of sightings of whales of each feeding aggregation divided by the total sightings of whales for each combination of season and sub-area of interest (Table 1). In general, all sightings were used. The exception was for determining the mixing rates of North and PCFG whales during the migratory season in the BCNC sub-area. For this analysis, the inland waters of Southern Vancouver Island and the Strait of Juan de Fuca were removed from the analysis because PCFG whales are disproportionately observed there. Similarly, Northern California waters were removed since telemetry data have shown that PCFG whales are also known to aggregate in northern California for feeding during the migratory season. Given the exceptional behaviour in such waters, the Workshop **agreed** to base the mixing rates on the rest of the BCNC sub-area. There were no reported sightings of WFG whales in California during the migratory season. The Workshop **agreed** to use the annual probability for a WNP whale being observed in the PCFG range by Moore and Weller (2013) for this mixing rate.

The mixing proportions need to be weighted when they are included in the objective function, minimized when fitting the model. There are no direct measurements of precision for the mixing rates in Table 1. However, one measure of precision would be the variance of the among-year estimates of mixing proportions. The Workshop **recommended** that these variances be determined by Punt and included in the model specifications.

The mixing rates in Table 1 are subject to various sources of considerable uncertainty (e.g. see the above discussion for the mixing rate estimates for the BCNC sub-area. The Workshop therefore **agreed** to conduct sensitivity analyses in which the mixing rates for PCFG and WFG whales are twice those reported in Table 2 (p. 11) for the BCNC and CA sub-areas (migratory season).

4.3.3 Abundance estimates

Tables 3 and 4 provide the abundance estimates for the California census and the PCFG. The abundance estimates of the PCFG could be updated before the 2015 meeting of the Scientific Committee (see Item 2.6 and 5). Table 5 provides the estimates of 1+ abundance for the Sakhalin sub-area. The Workshop **recommended** that Cooke provide a covariance matrix for these estimates.

Table 3

Estimates of absolute abundance (with associated standard errors) for the eastern North Pacific stock of gray whales based on shore counts (source: 1967/78-2006/07: Laake *et al*, 2012; 2006/07-2010/11: Durban *et al*, 2013).

Year	Estimate	CV	Year	Estimate	CV
1967/68	13426	0.094	1985/86	22921	0.081
1968/69	14548	0.080	1987/88	26916	0.058
1969/70	14553	0.083	1992/93	15762	0.067
1970/71	12771	0.081	1993/94	20103	0.055
1971/72	11079	0.092	1995/96	20944	0.061
1972/73	17365	0.079	1997/98	21135	0.068
1973/74	17375	0.082	2000/01	16369	0.061
1974/75	15290	0.084	2001/02	16033	0.069
1975/76	17564	0.086	2006/07	19126	0.071
1976/77	18377	0.080	2006/07	20750	0.060
1977/78	19538	0.088	2007/08	17820	0.054
1978/79	15384	0.080	2009/10	21210	0.046
1979/80	19763	0.083	2010/11	20990	0.044
1984/85	23499	0.089			

Table 4

Estimates of absolute abundance (with associated CVs) for 41°-52°N (the PCFG sub-area). Source: J. Laake, pers. commn).

Year	Estimate	CV	Year	Estimate	CV
1998	126	0.086	2006	200	0.106
1999	147	0.102	2007	193	0.133
2000	149	0.101	2008	207	0.088
2001	181	0.077	2009	206	0.098
2002	198	0.064	2010	194	0.094
2003	210	0.086	2011	197	0.080
2004	218	0.078	2012	209	0.073
2005	218	0.120			

Table 5

Indices of 1+ abundance for the Sakhalin sub-area (J.G. Cooke, pers. comm.)

Year	Estimate	CV	Year	Estimate	CV
1995	64	0.041	2004	114	0.006
1996	66.9	0.035	2005	119.2	0.006
1997	72.9	0.024	2006	125.2	0.007
1998	76.4	0.017	2007	126.8	0.008
1999	84.4	0.011	2008	128.4	0.01
2000	85.8	0.009	2009	128.9	0.011
2001	91.4	0.006	2010	133.9	0.012
2002	96.8	0.005	2011	137.8	0.013
2003	104.3	0.005	2012	149.4	0.019

Table 2

The catch mixing matrices for cases 3a, 3e, and 5a. The γs denote the estimable parameters of the catch mixing matrix and the χs denote values are varied in the tests of sensitivity. Note that the 'CA-3' sub-area is included so that the surveys cover all of the PCFG, Sakhalin and north feeding aggregations while the BCNC-3 sub-area is included so that the surveys for the BCNC sub-area pertain only to the PCFG feeding aggregation.

[a] Case 3a (no western stock)

Breeding Group	Sub-area/season														
Feeding Aggregation	VSC	KWJ	EJPJ	OS	SI	EKK	BSCS	SEA	BCNC (Jun.-Nov.)	BCNC (Dec.-May)	BCNC-3	CA (Jun.-Nov.)	CA (Dec.-May)	CA-3	M
Eastern															
WFG			1	1	1	1				γ_3			γ_6	1	1
North			γ_8				1	1	1	1		1	1	1	1
PCFG							χ_1	γ_1	γ_2	γ_4	1	γ_5	γ_7	1	1

[b] Case 3e (with western stock)

Breeding Group	Sub-area/season														
Feeding Aggregation	VSC	KWJ	EJPJ	OS	SI	EKK	BSCS	SEA	BCNC (Jun.-Nov.)	BCNC (Dec.-May)	BCNC.-3	CA (Jun.-Nov.)	CA (Dec.-May)	CA-3	M
Western	1	1	1	1											
Eastern															
WFG			χ_2[a]		**1**	1				γ_3			γ_6	1	1
North							1	1	1	1		1	1	1	1
PCFG							χ_1	γ_1	γ_3	γ_4	1	γ_5	γ_6	1	1

a – meant to capture the 'occasional' migration to E Sea of Japan/Pacific Coast of Japan.

[b] Case 5a (with western stock)

Breeding Group	Sub-area/season														
Feeding Aggregation	VSC	KWJ	EJPJ	OS	SI	EKK	BSCS	SEA	BCNC (Jun.-Nov.)	BCNC (Dec.-May)	BCNC-3	CA (Jun.-Nov.)	CA (Dec.-May)	CA-3	M
Western	1	1	1	1	γ_9										
Eastern															
WFG			χ_2[a]		1	1				γ_3			γ_5	1	1
North							1	1	1	1		1	1	1	1
PCFG							χ_1	γ_1	γ_2	γ_4	1	γ_5	γ_7	1	1

a – meant to capture the "occasional" migration to E Sea of Japan/Pacific Coast of Japan.

4.4 Development of trials to reflect uncertainty and anthropogenic removals

The Workshop reviewed the analyses in the SC/A15/GW1 and made the following recommendations regarding the model:

(1) bycatches should be removed from younger ages (<5 years) following the data for California (Heyning and Lewis, 1990). It **agreed** that Punt could consult the Steering Group if this specification led to an inability to mimic other data
(2) The catch mixing matrices were updated to more adequately reflect the recommendations from the 2014 Rangewide workshop (Table 2).

The Workshop **agreed** to the following sensitivity tests:

(1) different values for parameters (Punt will propose values and work with the Steering Group to finalise these intersessionally)
(2) a case in which the PCFG feeding aggregation is not treated as a separate 'population'. Punt will develop a set of specifications and provide these to the Steering Group intersessionally.

The Workshop **agreed** that preliminary projections should be undertaken prior to the 2015 Annual Meeting. These projections should be based on (a) setting the catches for the 'North' sub-area to the average catch in this sub-area over the last year, (b) setting the catching in the BCNC sub-area to number of strikes expected under the *SLA* selected for the PCFG by the Scientific Committee (IWC, 2013), and (c) setting bycatches by sub-area based on the assumption of constant effort. The set of the projections will be refined during the 2015 meeting of the Scientific Committee.

4.5 Consideration on conditioning

The age- and sex-structured population dynamics model is conditioned to estimates of abundance for the Sakhalin sub-area, the PCFG feed aggregation and the abundance estimates for California. The model is also conditioned to the mixing rates estimates.

5. WORKPLAN

The Workshop made a number of recommendations related to the comparison of photographic and genetic material (see Items 2.1 and 2.2). It **requests** that progress be reported to the 2015 Scientific Committee meeting. The importance of including information on confirmed non-matches or probable non-matches, as well as matches when presenting results was stressed.

The Workshop also **requested** that Weller and Brownell modify the table from Kato *et al.* (2014), adding new records and supplementing information on included records, as appropriate and present this to the 2015 Scientific Committee meeting.

The last Workshop had noted the importance of knowing the degree to which there was large-scale recruitment into the PCFG during the period prior to around 1998 (which would have to have been from an external source) to evaluate the status of the PCFG. Laake reported that some progress has been made and the Workshop **reiterated** its previous recommendation (IWC, 2015a) and looked forward to a progress report at the 2015 Scientific Committee meeting.

With a view to narrowing the confidence range for the proportion of Sakhalin whales that migrate east, the Workshop **recommended** a number of priority analyses under Item 3.1. It recognised that these would take time but looked forward to any reports of progress at the 2015 Scientific Committee meeting.

The Committee **welcomed** the progress already made by Punt and the additional specifications and scenarios developed at the present Workshop. A number of the recommendations under Item 4 should lead to additional results becoming available at the 2015 Scientific Committee meeting. It **commended** Punt for his efforts thus far and requested that he work with the existing intersessional steering group to progress the modelling work as far as practicable in the time available.

The Workshop recognised that an important driver for the present work was the need to update the present IWC/IUCN Conservation Management Plan for western gray whales. It **recommends** that focussed discussions on how best to achieve this take place at the 2015 Scientific Committee meeting.

6. ADOPTION OF REPORT

The report was adopted at 1645 on 3 April 2015 subject to final editorial work by the rapporteurs and the development of the figures related to the various stock structure hypotheses given in Annex E. The Chair of the Workshop thanked the participants for the constructive dialogue, the rapporteurs for their hard work and Punt for his usual exceptional modelling efforts. He also thanked the Southwest Fisheries Science Center for their excellent hospitality and facilities. The Workshop thanked the Chair for his usual efficient and fair handling of the meeting.

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Annex A
List of Participants

USA

Robert Brownell Jr

Aimee Lang

Jeff Laake

Wayne Perryman

Jon Scordino

Paul Wade

David Weller

Invited Participants

John Bickham

John Brandon

Justin Cooke

André Punt

Randall Reeves

IWC Secretariat

Greg Donovan

Annex B

Agenda

1. Introductory items

    1.1 Convenor's opening remarks

    1.2 Election of Chair

    1.3 Appointment of rapporteurs

    1.4 Adoption of Agenda

    1.5 Documents and data available

2. Short report on progress on 'non-modelling' recommendations

    2.1 Preliminary comparison of identified gray whales in Mexico, off central California and in the PCFG with a focus on mothers and calves

    2.2 Comparison of photographs (and genetic material) of gray whales from areas of the Okhotsk Sea and elsewhere in Asia with the Sakhalin and Kamchatka catalogues

    2.3 Development of Single Nucleotide Polymorphisms (SNP) assays for use with gray whales

    2.4 Increased sample size and coverage from the eastern North Pacific

    2.5 Continued telemetry studies

    2.6 Improved abundance and trend estimates for the PCFG by identifying and using additional photographic sources

    2.7 Improved estimates of western North Pacific catches 1890-1910

    2.8 Improved estimates for future ship strikes and bycatches throughout the North Pacific

3 Progress report on modelling-related issues

    3.1. Putting bounds on the proportion of Sakhalin whales that migrate to the eastern North Pacific

    3.3 Development of an age- and sex-structured model

4. Update modelling framework

    4.1 Review of the nomenclature for stocks, sub-stocks and sub-areas

    4.2. Summary of priority stock structure hypotheses from first workshop

    4.3 Finalise datasets by stock structure hypothesis

        4.3.1 Catches

        4.3.2 Mixing rates

    4.4 Development of trials to reflect uncertainty and anthropogenic removals

    4.5 Consideration on conditioning

5. Workplan

6. Adoption of report

Annex C
List of documents

SC/A15/GW1 Punt, A.E. An Age-Structured Model or Exploring the Conceptual Models Developed for Gray Whales in the North Pacific.

SC/A15/GW2 Cooke, J.G. Implications of observed whale movements on the relationship between the Sakhalin gray whale feeding aggregation and putative breeding stocks of the gray whale.

Annex D

Non-whaling anthropogenic mortality of gray whales

SCORDINO, REEVES AND BROWNELL

Scordino and Mate (2012) summarised bycatch and ship strike mortality from stranding databases, human-whale interaction databases and ship strike databases maintained by NOAA's Northwest Region and Southwest Region (databases did not include events in Alaska). Their summary also included bycatches and ship strikes reported by Baird *et al.* (2002 for 1990-95 in British Columbia and all reported ship strikes and bycatch events from 1978-2010 in the USA. The authors chose to calculate annual human-caused mortality rates based on data from 1990-2010 for the USA and 1990-1995 for Canada waters because fishing effort in the two jurisdictions was more similar in those years than earlier in the time-series and because stranding networks in the USA were well established by 1990, giving more confidence that animals stranded in the USA with signs of human-caused mortality would have been reported.

Stranding reports and in particular at-sea reports of ship strikes and entanglements were often hard to interpret from the information available. The authors removed reports of free-swimming whales that they judged to be duplicative based on proximity in timing and location and on ancillary information such as type of entangling gear. All bycatch reports were graded into six categories based on the probability that a whale died due to entanglement injuries. The six categories were: 1 – cause of death diagnosed as entanglement; 2 – entanglement may have been cause of death; 3 – disentanglement efforts initiated and only partly successful, with final status of the individual unknown; 4 – disentanglement efforts initiated and fully successful or whale managed to free itself; 5 – free-swimming with entangling gear, final status unknown; and 6 – status of the individual unknown but last seen alive. All reports except those in category 4 (whale successfully disentangled) were included in analyses of annual bycatch rates. A similar approach was taken with ship strike data. The six categories used were: 1 – cause of death diagnosed as ship strike; 2 – cause of death suspected to have been ship strike; 3 – whale free-swimming but injured and likely to die; 4 – whale free-swimming, injured from ship strike, and may die; 5 – whale struck by a boat but free-swimming and unlikely to die; and 6 –whale last seen alive and its status unknown. All categories of ship strikes were used for computing ship strike rates for 1990-2010 although whales classified as category 5 were thought unlikely to die. The results of the analysis were summarised in Table 2 of Scordino and Mate (2012) with estimated annual human-caused mortality (bycatch and ship strike combined) of 1.845 PCFG whales (analysis assumed California whales in summer were PCFG whales) and 4.555 ENP/WFG whales.

In 2014, Scordino *et al.* (2014) presented a new estimate of annual bycatch and ship strike rates for the time period of 2008-2012 using a classification procedure developed by NOAA to account for the uncertainty in outcome of injuries to large whales due to entanglements and ship strikes (NOAA, 2012). This procedure makes it possible to prorate mortality values for injuries based on the known fate of individual whales observed with similar injuries in the past (table ZZ from NOAA (2012). Gray whale deaths and injuries were documented through fisheries observer programmes, self-reporting by fishermen and sailing captains, reporting by the public and examinations of dead whales on the beach in the USA and Canada. Every report was documented in a Canadian or US government database. Based on descriptions in the databases, each event was determined to have been either a death, a serious injury, or a non-serious injury, based on NOAA (2012). All US events were assessed for serious vs non-serious injury by a NOAA working group (Carretta *et al.*, 2014) and that group's results were used as the basis for scoring the events reported by Scordino *et al.* (2014). Results of the analysis are presented in Table 1.

Table 1

Deaths and prorated serious injuries of gray whales due to ship strike and bycatch in US and Canadian waters, 2008-2012, from Scordino *et al.* (2014).

	Deaths plus prorated injuries		Average (2008-2012)	
Region	Feeding	Migrating	Feeding	Migrating
Far North	0	0.75	0	0.15
Kodiak	0	0	0	0
SE Alaska	2.75	0.75	0.55	0.15
Puget Sound	0	1	0	0.20
NBC-NCA	4.02	7.75	0.80	1.55
California	6	16.05	1.20	3.21
Total	12.8	26.3	2.55	5.26

Data from Scordino and Mate (2012), Scordino *et al.* (2014), Baird *et al.* (2002) and Heyning and Lewis (1990) are presented in Table 4 (ship strikes) and Table 5 (bycatch). Total ship strikes and bycatch by year, season and area presented in Tables 2 (feeding season) and 3 (migratory season). Methodology from NOAA (2012) could not be applied to data from sources other than Scordino *et al.* (2014). To make interpretation of injuries consistent by year injuries were not prorated.

Table 2

Observed deaths of gray whales in the feeding season (June-November) due to ship strike and bycatch in US and Canada from 1978-2012 (see table A). All injured whales, whether or not noted to be disentangled, are assumed dead for the Dead & Injured column.

	California		NBC-NCA		Southeast Alaska	
Year Bin	Dead	Dead & Injured	Dead	Dead & Injured	Dead	Dead & Injured
1978-1982	0	0	1	1	0	0
1983-1987	2	3	0	0	0	0
1988-1992	1	3	3	3	0	0
1993-1997	0	0	1	3	0	0
1998-2002	1	4	4	4	0	0
2003-2007	0	1	3	5	0	0
2008-2012	2	6	1	5	0	3

Table 3

Observed deaths of gray whales in the migratory season (December-May) due to ship strike and bycatch in US and Canada from 1978-2012 (see tables A and B). All injured whales, whether or not noted to be disentangled, are assumed dead for the Dead & Injured column.

	California		NBC-NCA		Southeast Alaska		Far North and Puget Sound	
Year Bin	Dead	Dead & Injured	Dead	Dead & Injured	Dead	Dead & Injured	Dead	Dead & Injured
1978-1982	2	2	0	2	0	0	0	0
1983-1987	16	42	6	7	0	0	0	0
1988-1992	9	29	0	1	0	0	0	0
1993-1997	5	15	4	5	0	0	0	0
1998-2002	1	7	0	0	0	0	0	0
2003-2007	0	6	5	12	0	0	0	0
2008-2012	7	22	4	8	0	1	1	2

Table 4

Ship strike deaths, injuries, and combined total mortality by region, year, and season for gray whales in the eastern North Pacific. Injuries were prorated as mortalities following methods of NOAA (2012) for Scordino *et al*., 2014

Year	Region	Season	Deaths	Injuries	Total	Source
1985	NBC-NCA	Migratory	1	0	1	Scordino and Mate 2011
1987	California	Migratory	3	0	3	Scordino and Mate 2011
1988	California	Migratory	1	0	1	Scordino and Mate 2011
1991	California	Migratory	3	0	3	Scordino and Mate 2011
1993	California	Migratory	1	0	1	Scordino and Mate 2011
1994	California	Migratory	1	0	1	Scordino and Mate 2011
1995	California	Migratory	0	3	3	Scordino and Mate 2011
1995	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011
1997	NBC-NCA	Migratory	1	0	1	Scordino and Mate 2011
1998	California	Migratory	1	3	4	Scordino and Mate 2011
1999	California	Migratory	1	1	2	Scordino and Mate 2011
2001	California	Migratory	0	1	1	Scordino and Mate 2011
2003	California	Migratory	1	0	1	Scordino and Mate 2011
2005	California	Migratory	2	0	2	Scordino and Mate 2011
2006	California	Migratory	2	2	4	Scordino and Mate 2011
2007	California	Migratory	2	0	2	Scordino and Mate 2011
2008	California	Migratory	2	0	2	Scordino *et al.* 2014[a]
2009	NBC-NCA	Migratory	1	0	1	Scordino *et al.* 2014[a]
2009	NBC-NCA	Feeding	0	1	1	Scordino *et al.* 2014[a]
2009	Puget Sound	Migratory	1	0	1	Scordino *et al.* 2014[a]
2009	California	Migratory	0	2	2	Scordino *et al.* 2014[a]
2008	NBC-NCA	Feeding	1	0	1	Scordino *et al.* 2014[a]
2010	California	Migratory	0	2	2	Scordino *et al.* 2014[a]
2011	California	Migratory	0	4	4	Scordino *et al.* 2014[a]

Table 5

Deaths, injuries, and combined total mortality due to bycatch by region, year and season for gray whales in the eastern North Pacific.

Year	Region	Season	Deaths	Injuries	Total	Source	
2008	NBC-NCA	Feeding	1	1	2	Scordino *et al*. 2014	
2009	NBC-NCA	Feeding	0	2	2	Scordino *et al*. 2014	
2010	California	Feeding	0	1	1	Scordino *et al*. 2014	
2011	California	Feeding	1	2	3	Scordino *et al*. 2014	
2011	Southeast Alaska	Feeding	0	1	1	Scordino *et al*. 2014	
2012	California	Feeding	1	1	2	Scordino *et al*. 2014	
2012	NBC-NCA	Feeding	0	1	1	Scordino *et al*. 2014	
2012	Southeast Alaska	Feeding	0	2	2	Scordino *et al*. 2014	
2008	California	Migratory	2	0	2	Scordino *et al*. 2014	
2009	California	Migratory	1	3	4	Scordino *et al*. 2014	
2009	NBC-NCA	Migratory	1	1	2	Scordino *et al*. 2014	
2009	Puget Sound	Migratory	1	0	1	Scordino *et al*. 2014	
2009	Southeast Alaska	Migratory	0	1	1	Scordino *et al*. 2014	
2010	California	Migratory	1	3	4	Scordino *et al*. 2014	
2010	NBC-NCA	Migratory	1	2	3	Scordino *et al*. 2014	
2011	California	Migratory	1	2	3	Scordino *et al*. 2014	
2012	California	Migratory	2	7	9	Scordino *et al*. 2014	
2012	Far North	Migratory	0	1	1	Scordino *et al*. 2014	
2012	NBC-NCA	Migratory	2	1	3	Scordino *et al*. 2014	
1983	California	Migratory	1	0	1	Scordino and Mate 2011	
1984	California	Migratory	2	1	3	Scordino and Mate 2011	
1985	California	Migratory	5	14	19	Scordino and Mate 2011	
1986	California	Feeding	1	0	1	Scordino and Mate 2011	
1987	California	Migratory	2	8	10	Scordino and Mate 2011	
1987	California	Feeding	1	1	2	Scordino and Mate 2011	
1988	California	Migratory	1	8	9	Scordino and Mate 2011	
1988	California	Feeding	0	1	1	Scordino and Mate 2011	
1989	California	Migratory	3	4	7	Scordino and Mate 2011	
1990	California	Migratory	2	3	5	Scordino and Mate 2011	
1991	California	Migratory	2	1	3	Scordino and Mate 2011	
1992	California	Migratory	1	2	3	Scordino and Mate 2011	
1990	California	Feeding	1	0	1	Scordino and Mate 2011	
1991	California	Feeding	0	1	1	Scordino and Mate 2011	
1993	California	Migratory	0	1	1	Scordino and Mate 2011	
1994	California	Migratory	1	2	3	Scordino and Mate 2011	
1995	California	Migratory	1	2	3	Scordino and Mate 2011	
1996	California	Migratory	2	2	4	Scordino and Mate 2011	
1997	California	Migratory	1	3	4	Scordino and Mate 2011	
1998	California	Migratory	0	1	1	Scordino and Mate 2011	
1998	California	Feeding	0	2	2	Scordino and Mate 2011	
1999	California	Migratory	0	1	1	Scordino and Mate 2011	
1999	California	Feeding	1	0	1	Scordino and Mate 2011	
2000	California	Migratory	1	2	3	Scordino and Mate 2011	
2000	California	Feeding	0	1	1	Scordino and Mate 2011	
2002	California	Migratory	0	2	2	Scordino and Mate 2011	
2003	California	Migratory	0	2	2	Scordino and Mate 2011	
2004	California	Migratory	0	2	2	Scordino and Mate 2011	
2004	California	Feeding	0	1	1	Scordino and Mate 2011	
2005	California	Migratory	0	1	1	Scordino and Mate 2011	
2007	California	Migratory	0	1	1	Scordino and Mate 2011	
1978	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
1981	NBC-NCA	Migratory	0	2	2	Scordino and Mate 2011	
1983	NBC-NCA	Migratory	2	0	2	Scordino and Mate 2011	
1984	NBC-NCA	Migratory	1	1	2	Scordino and Mate 2011	
1988	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
1990	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
1991	NBC-NCA	Migratory	0	1	1	Scordino and Mate 2011	
1993	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
1994	NBC-NCA	Migratory	2	0	2	Scordino and Mate 2011	
1994	NBC-NCA	Feeding	0	1	1	Scordino and Mate 2011	
1995	NBC-NCA	Migratory	1	0	1	Scordino and Mate 2011	

1996	NBC-NCA	Migratory	1	0	1	Scordino and Mate 2011	
1997	NBC-NCA	Migratory	0	1	1	Scordino and Mate 2011	
1998	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
1999	NBC-NCA	Feeding	2	0	2	Scordino and Mate 2011	
2002	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
2003	NBC-NCA	Migratory	1	2	3	Scordino and Mate 2011	
2003	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
2004	NBC-NCA	Migratory	2	2	4	Scordino and Mate 2011	
2004	NBC-NCA	Feeding	1	0	1	Scordino and Mate 2011	
2005	NBC-NCA	Migratory	1	1	2	Scordino and Mate 2011	
2005	NBC-NCA	Feeding	1	1	2	Scordino and Mate 2011	
2006	NBC-NCA	Migratory	1	1	2	Scordino and Mate 2011	
2007	NBC-NCA	Migratory	0	1	1	Scordino and Mate 2011	
2007	NBC-NCA	Feeding	0	1	1	Scordino and Mate 2011	
1983	NBC-NCA	Migratory	2	0	2	Baird *et al.* 2002	
1984	NBC-NCA	Migratory	1	0	1	Baird *et al.* 2002	
1988	NBC-NCA	Feeding	1	0	1	Baird *et al.* 2002	
1993	NBC-NCA	Feeding	0	1	1	Baird *et al.* 2002	
1981	California	Migratory	1	0	1	Heyning and Lewis 1990[a]	
1982	California	Migratory	1	0	1	Heyning and Lewis 1990[a]	
1983	California	Migratory	1	0	1	Heyning and Lewis 1990[a]	
1985	California	Migratory	4	0	4	Heyning and Lewis 1990[a]	
1986	California	Migratory	0	2	2	Heyning and Lewis 1990[a]	
1987	California	Migratory	1	1	2	Heyning and Lewis 1990[a]	
1988	California	Migratory	0	1	1	Heyning and Lewis 1990[a]	
1989	California	Migratory	0	1	1	Heyning and Lewis 1990[a]	

[a] Only reports of bycatch included in Heyning and Lewis (1990) that were not found in the stranding and human interaction databases maintained by NOAA's Southwest Regional Office summarized in Scordino and Mate (2011) were included in this table.

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Annex E

Schematic representations of the stock structure hypotheses

GEOGRAPHIC DIAGRAMS

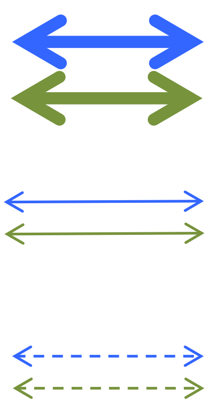
Geographic areas utilized by gray whales are illustrated with colored boxes:

Feeding region

Migratory region

Wintering region

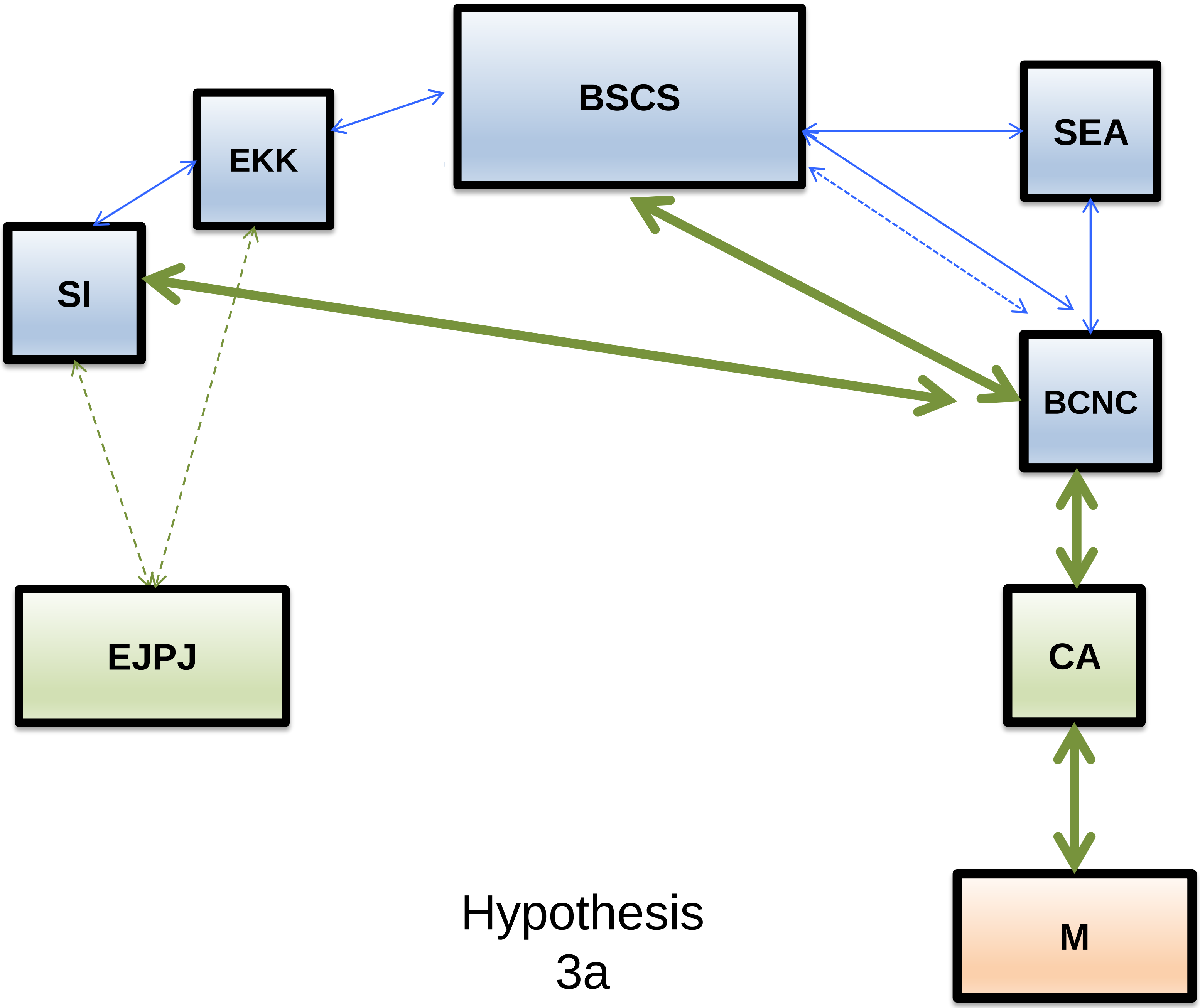
Arrows represent movements between geographic areas, with blue representing movements between feeding regions and green representing migratory movements:



Solid thick lines with arrows denote movements between regions of a significant proportion of individuals using the area

Solid thin lines with arrows denote limited movements between regions

Dashed thin lines with denote occasional movement between regions of small number of individuals



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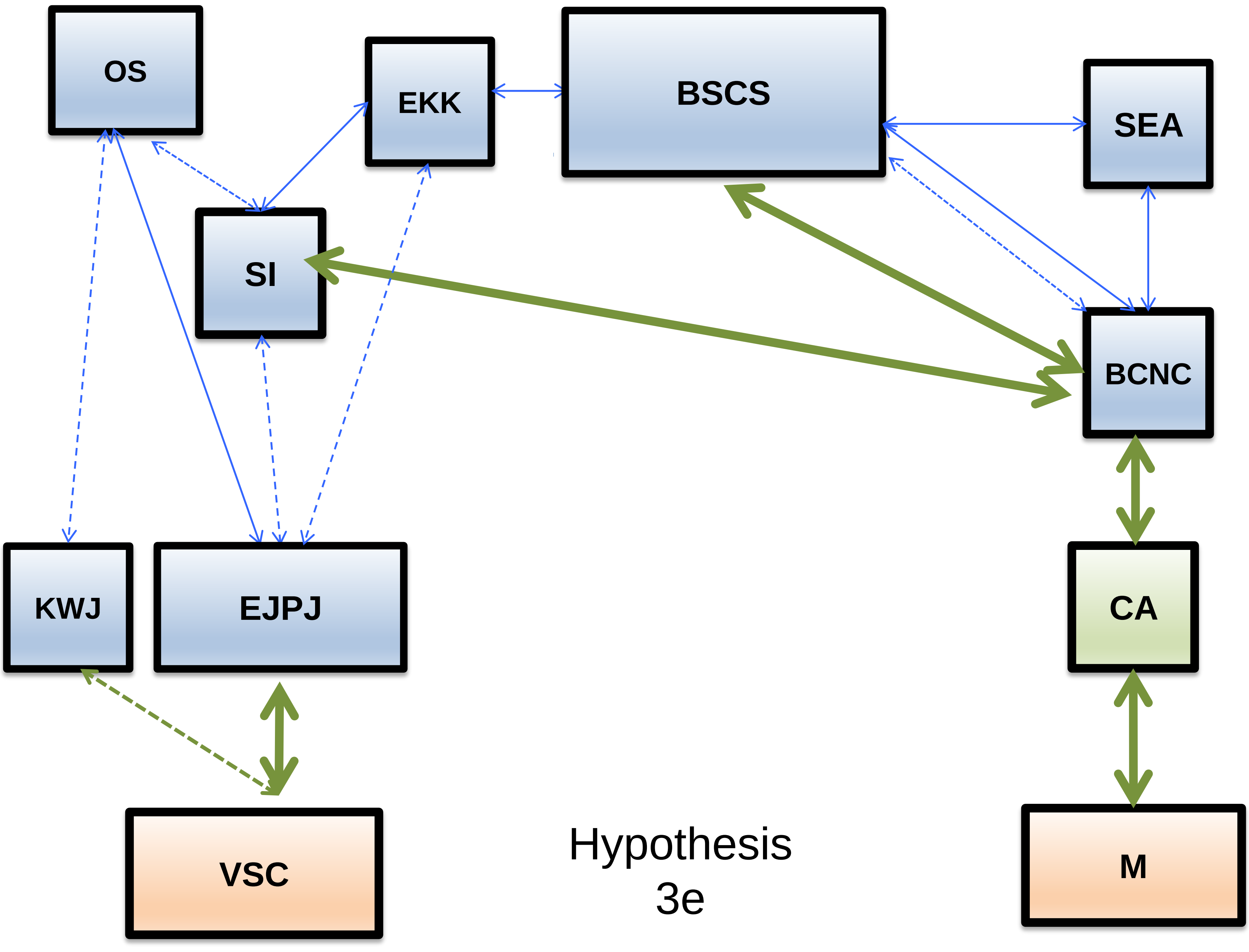

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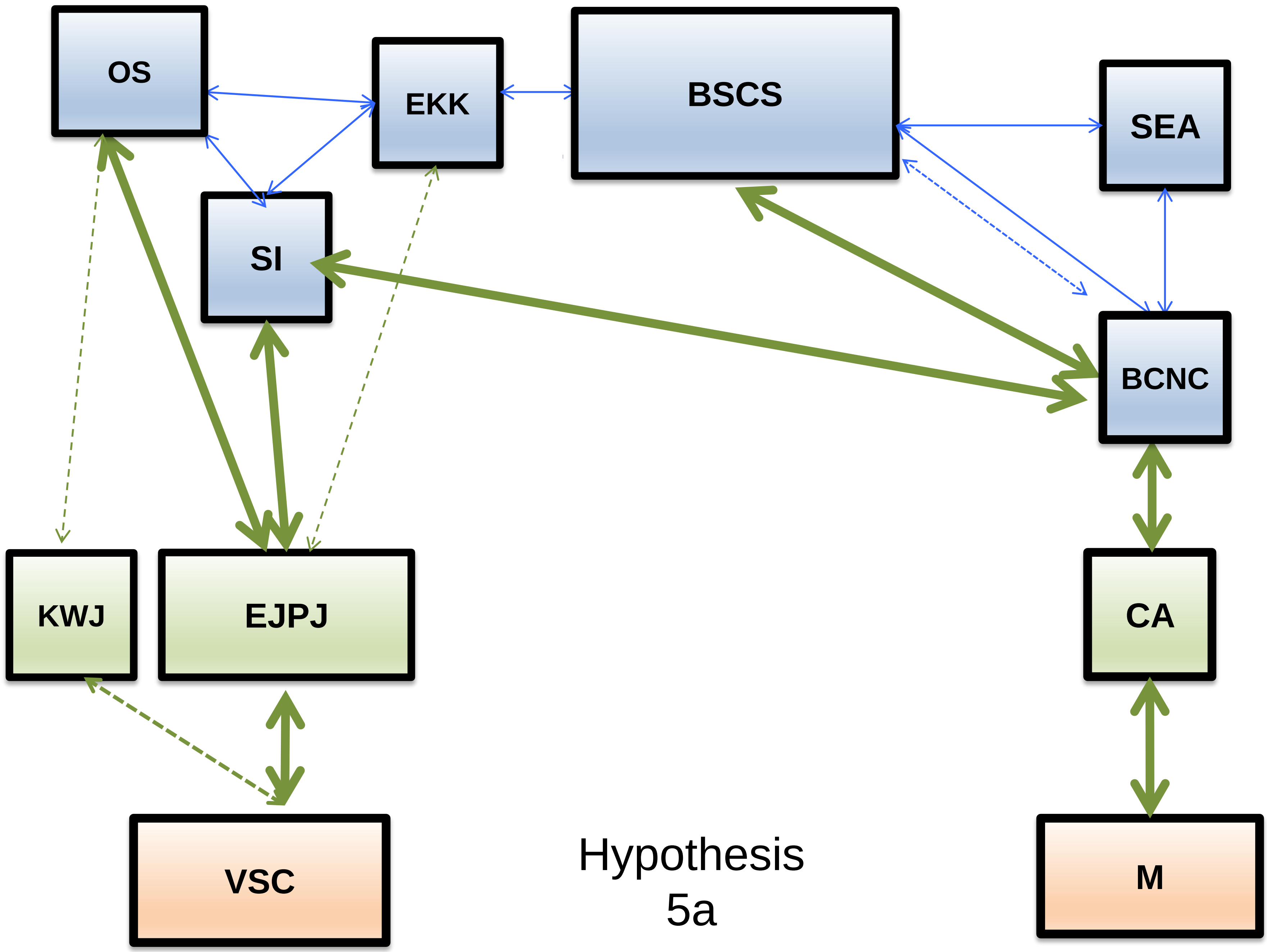
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Hypothesis
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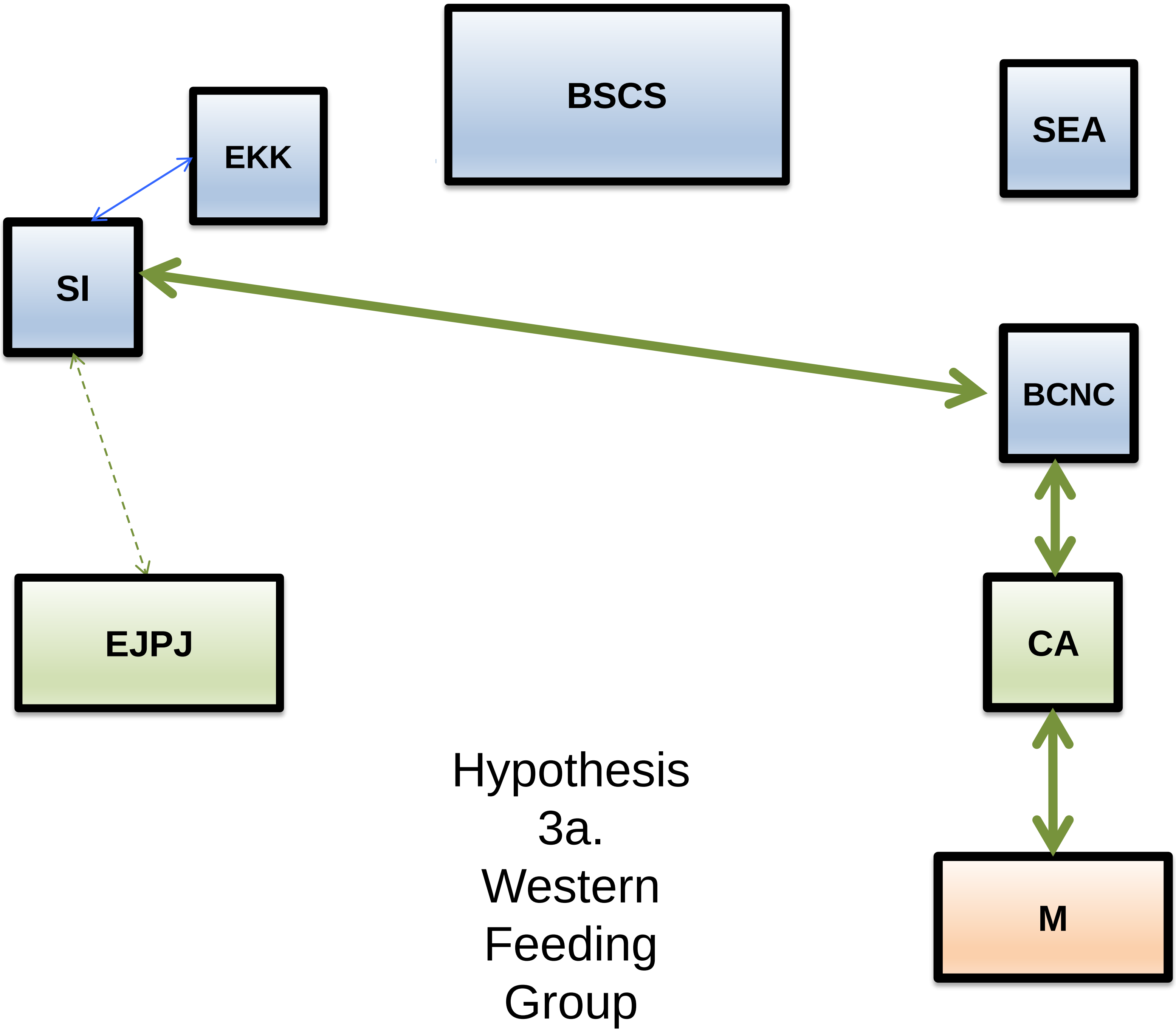
GEOGRAPHIC DIAGRAMS BY FEEDING AGGREGATION/STOCK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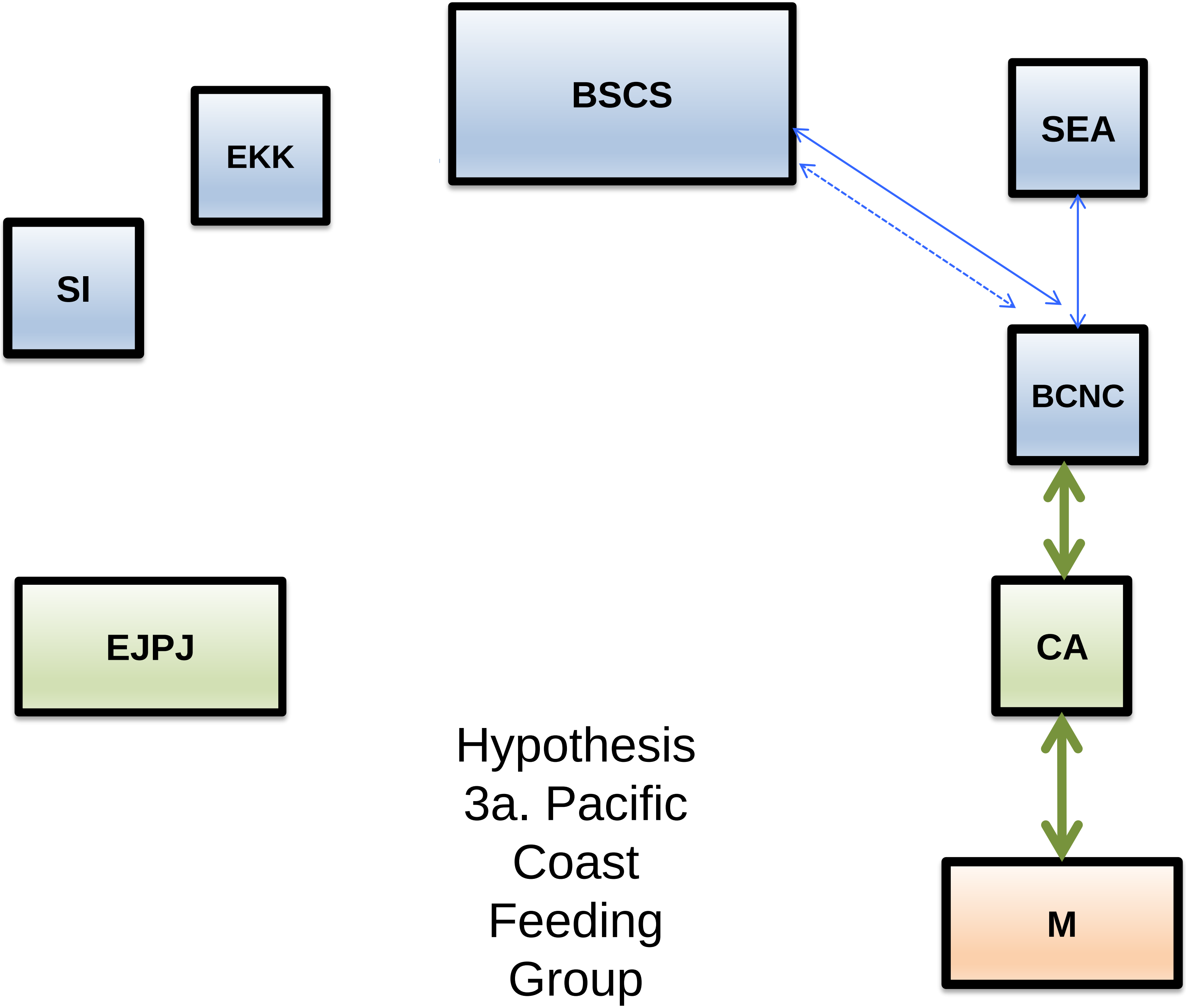
Group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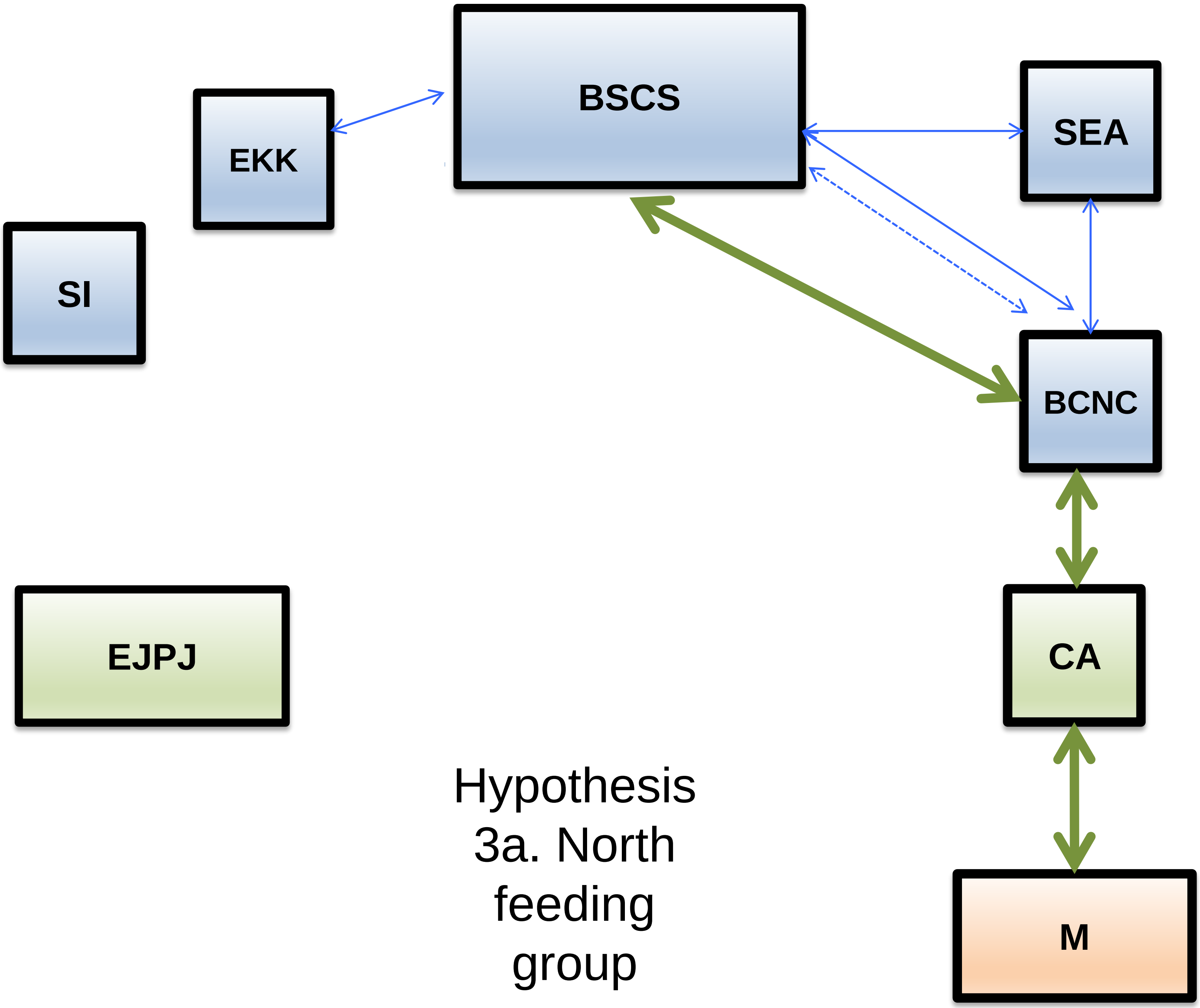
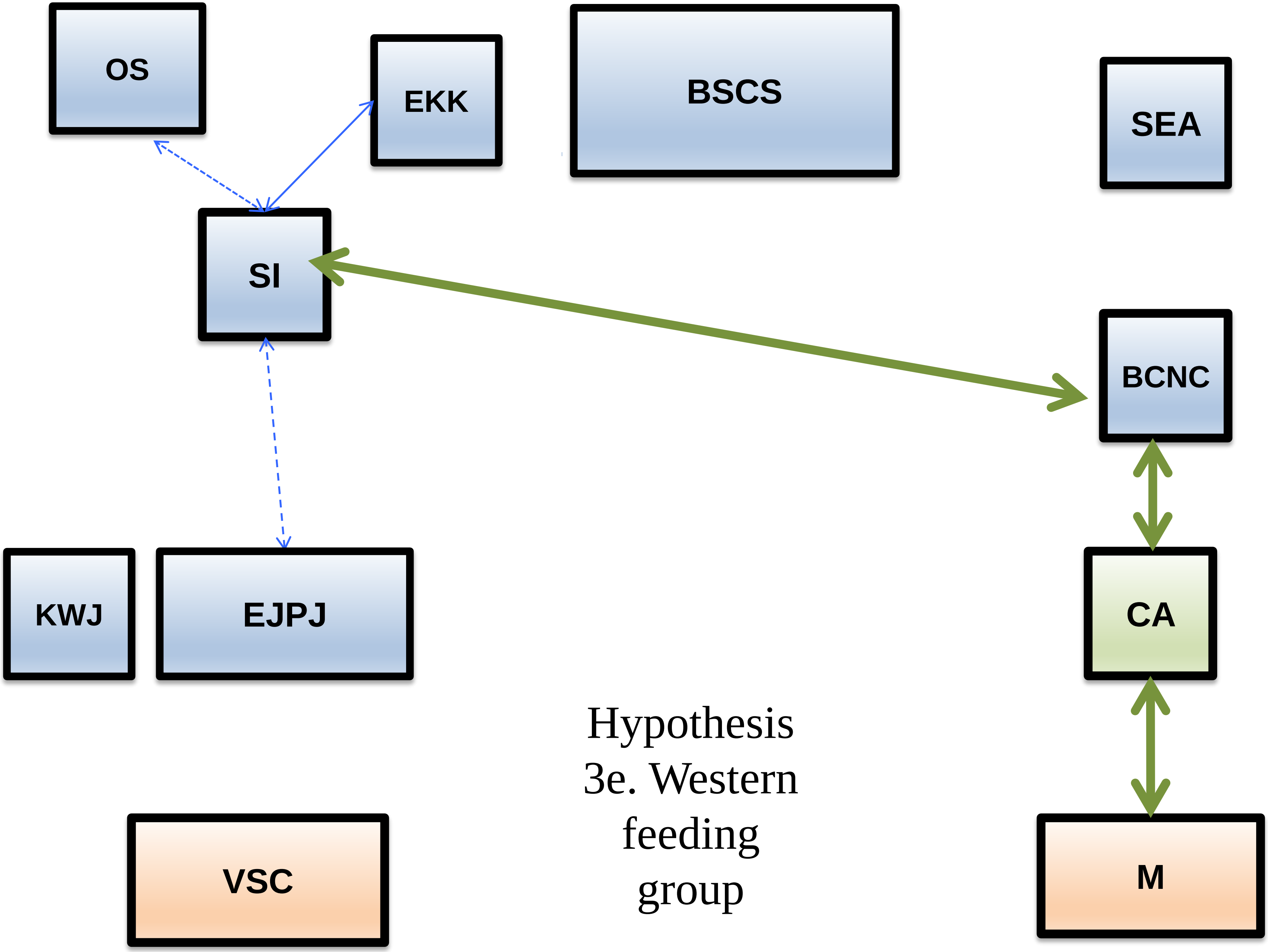
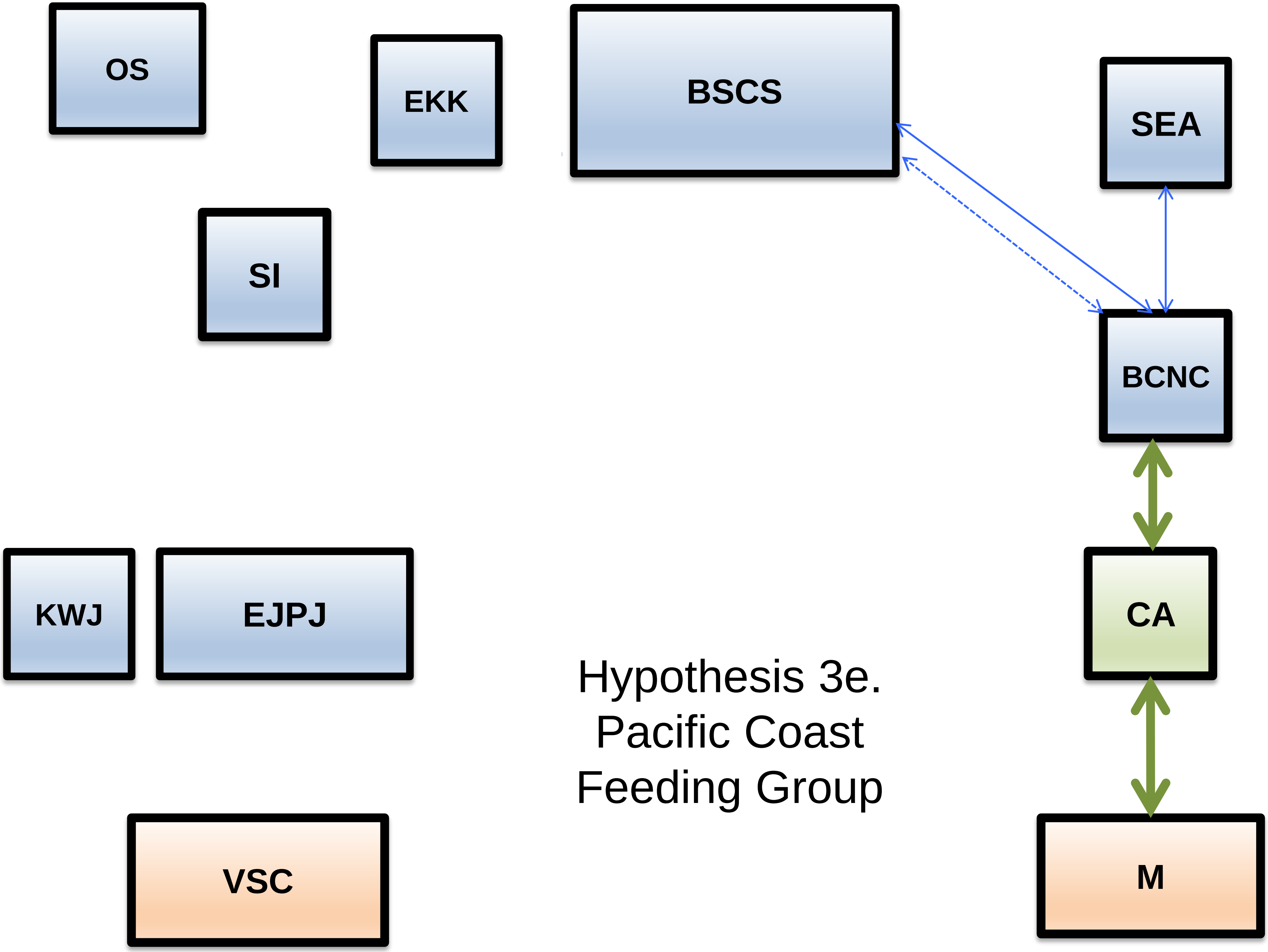
Hypothesis 3a. Pacific Coast Feeding Group



Hypothesis 3a. North feeding group



Hypothesis 3e. Western feeding group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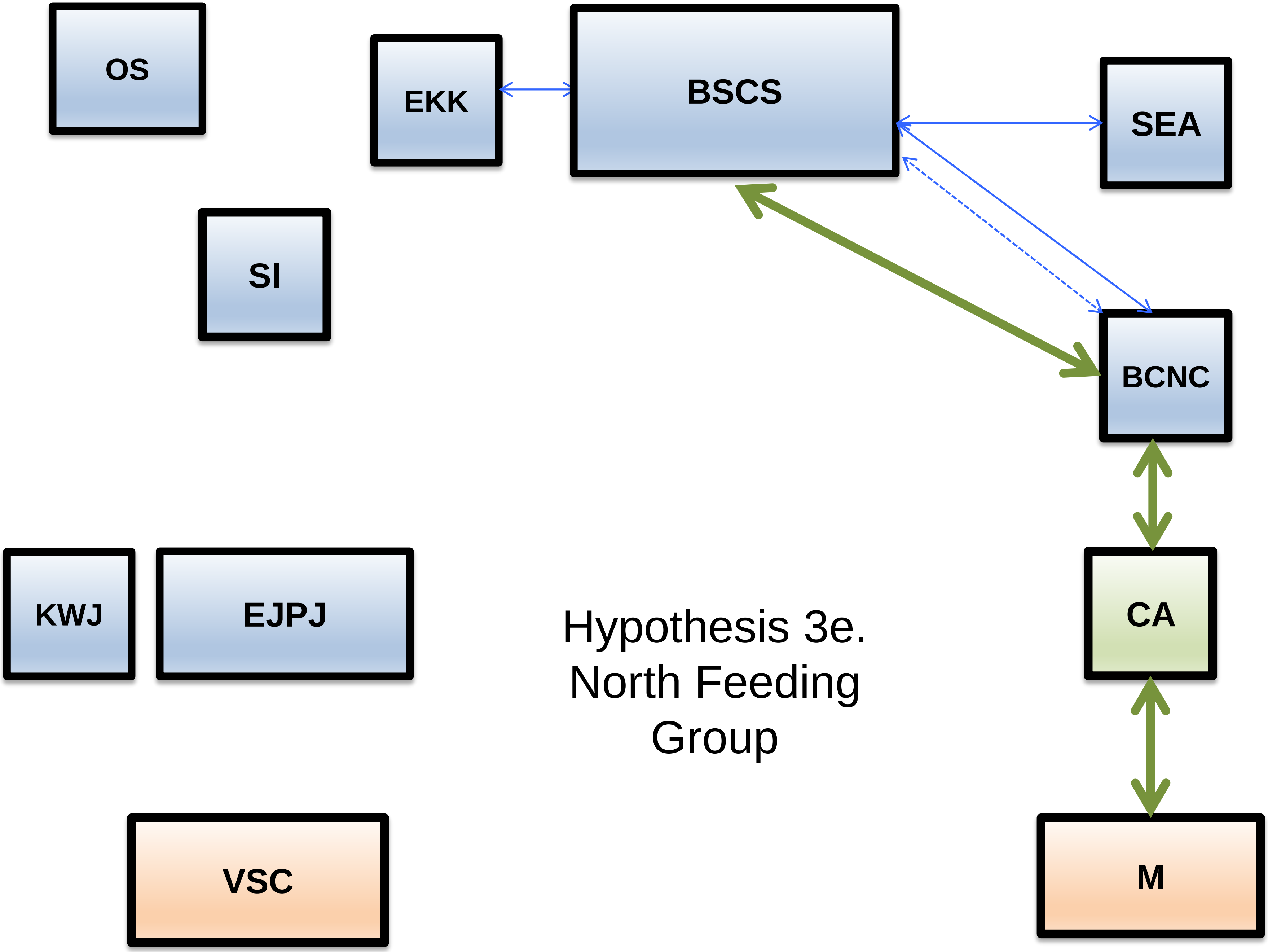
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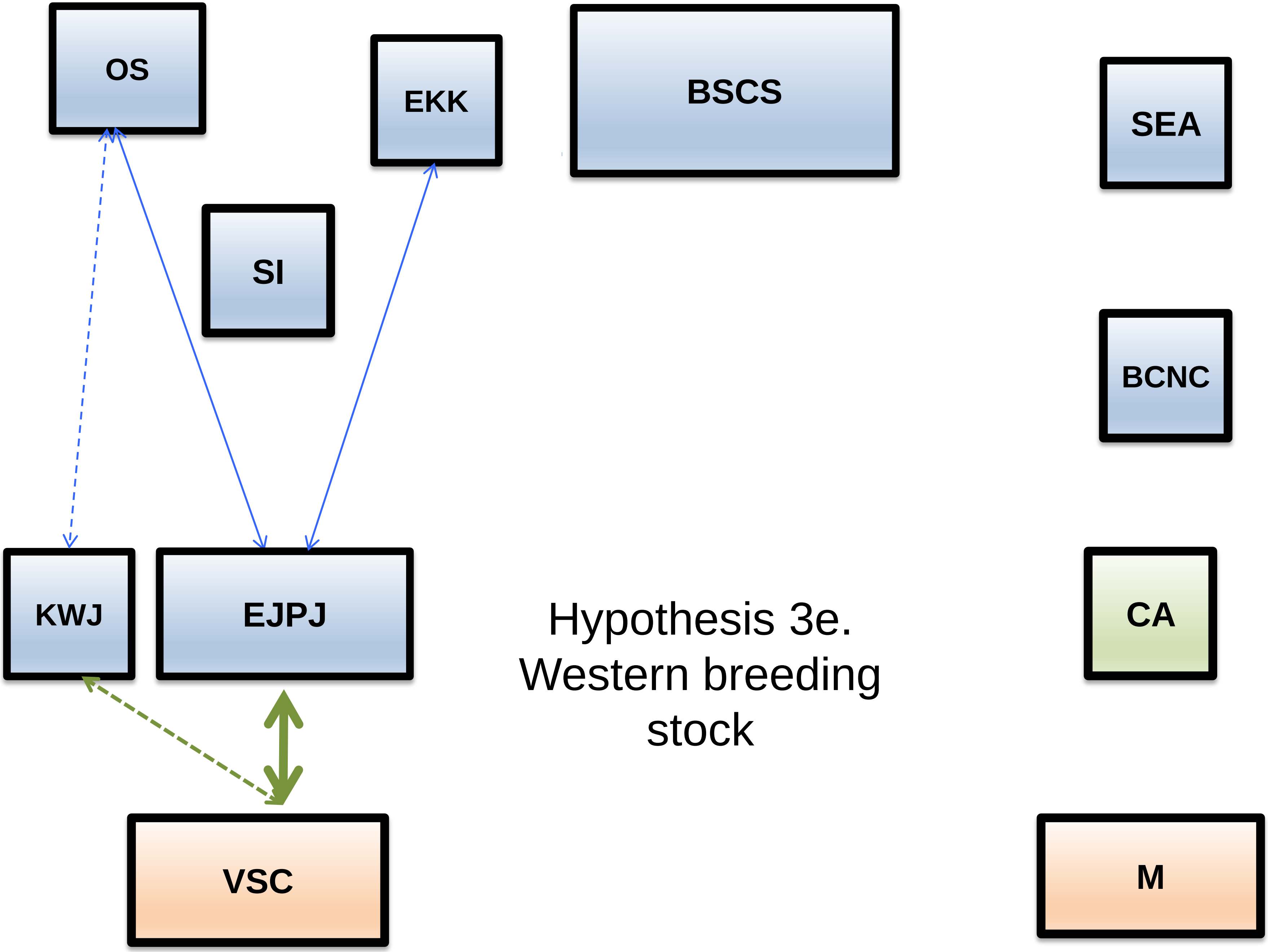
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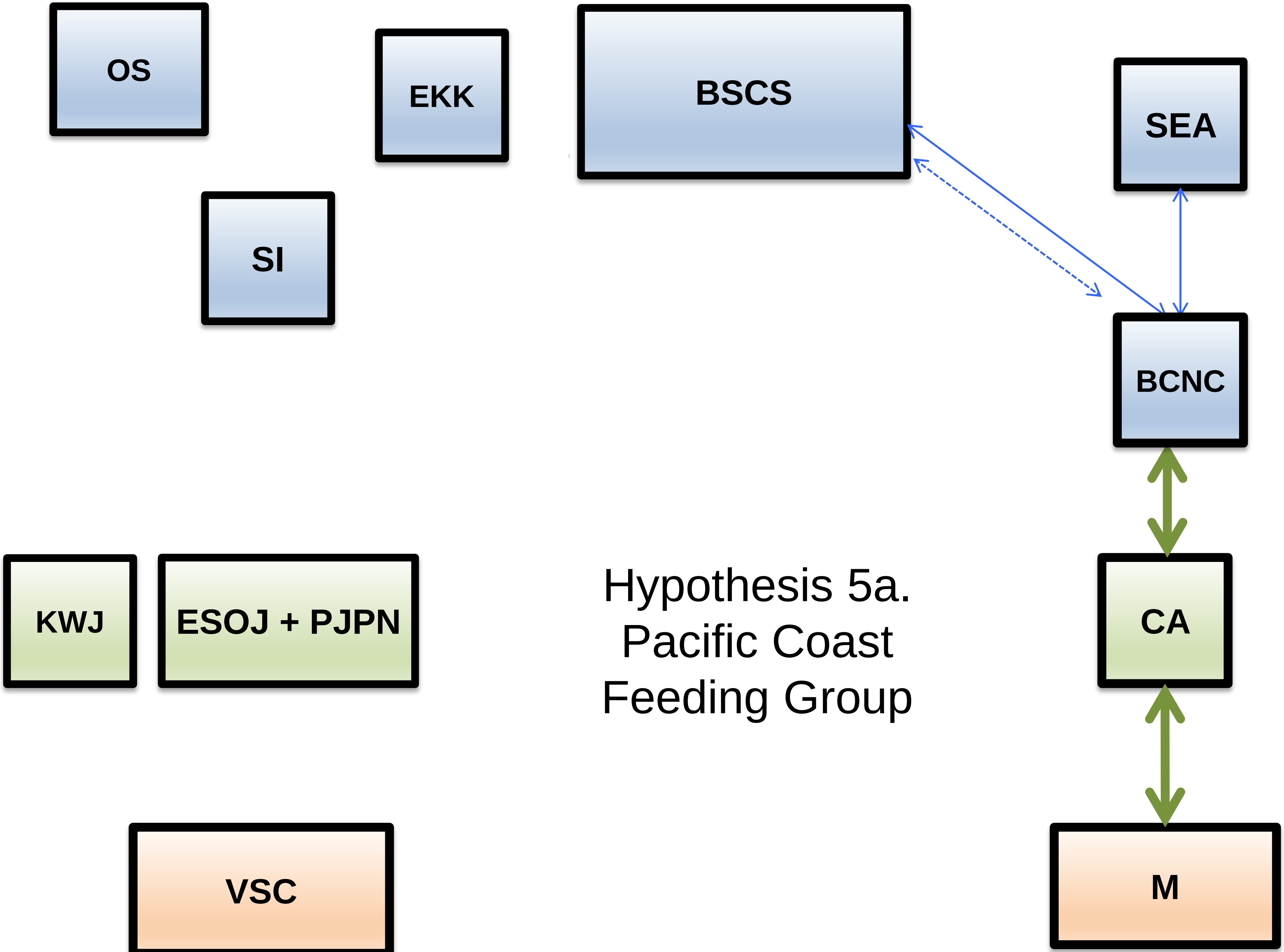
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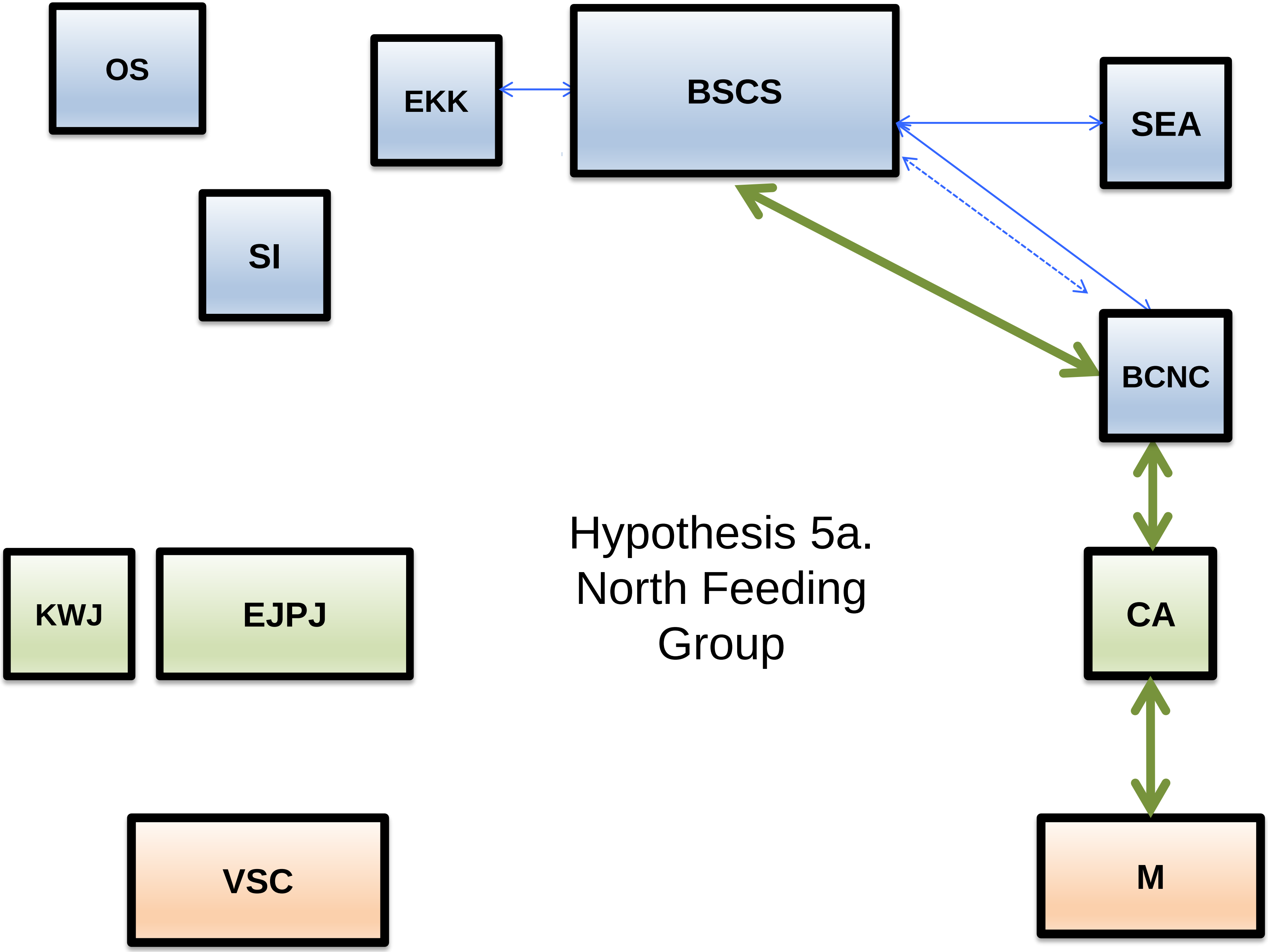
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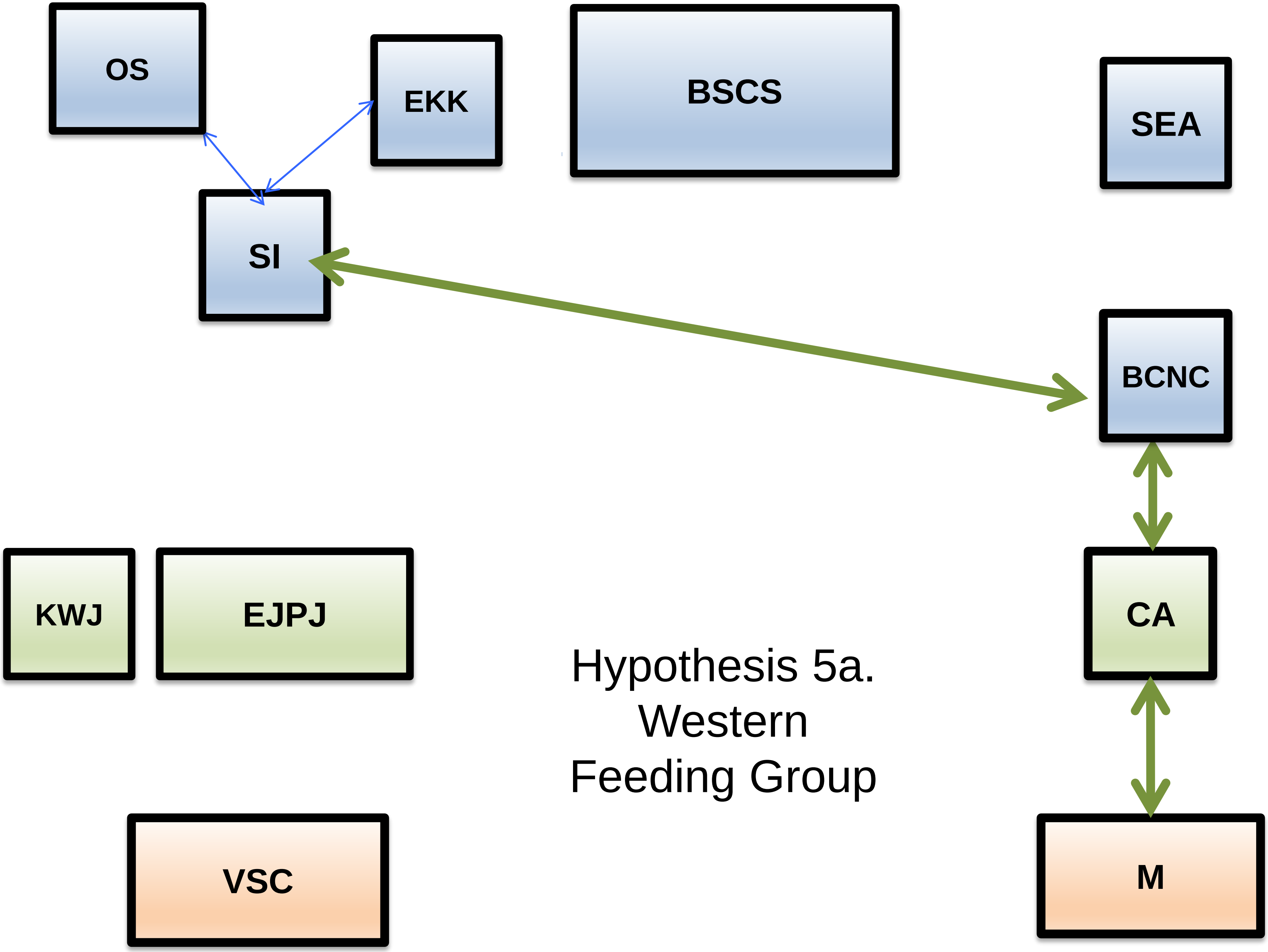
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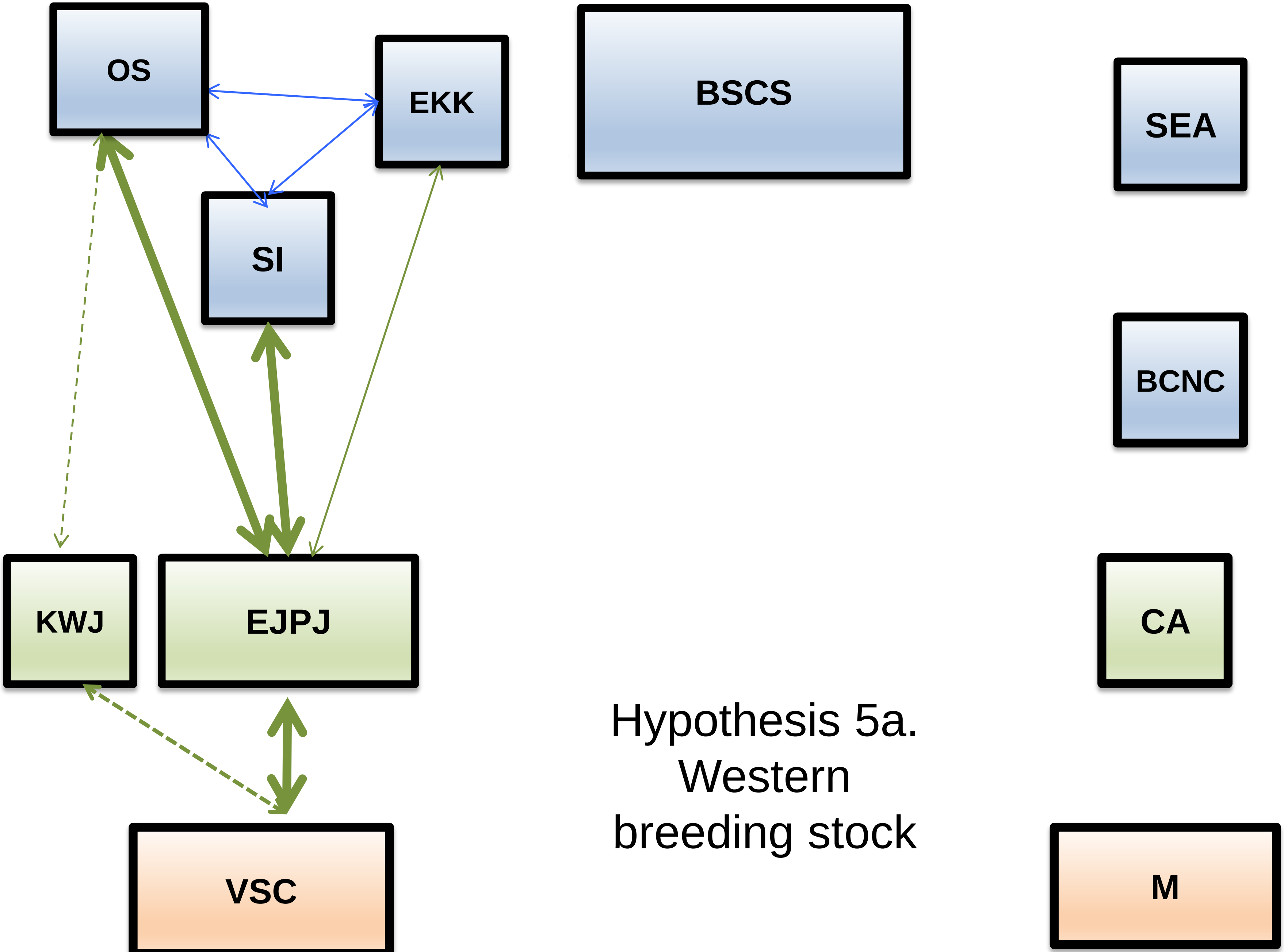
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